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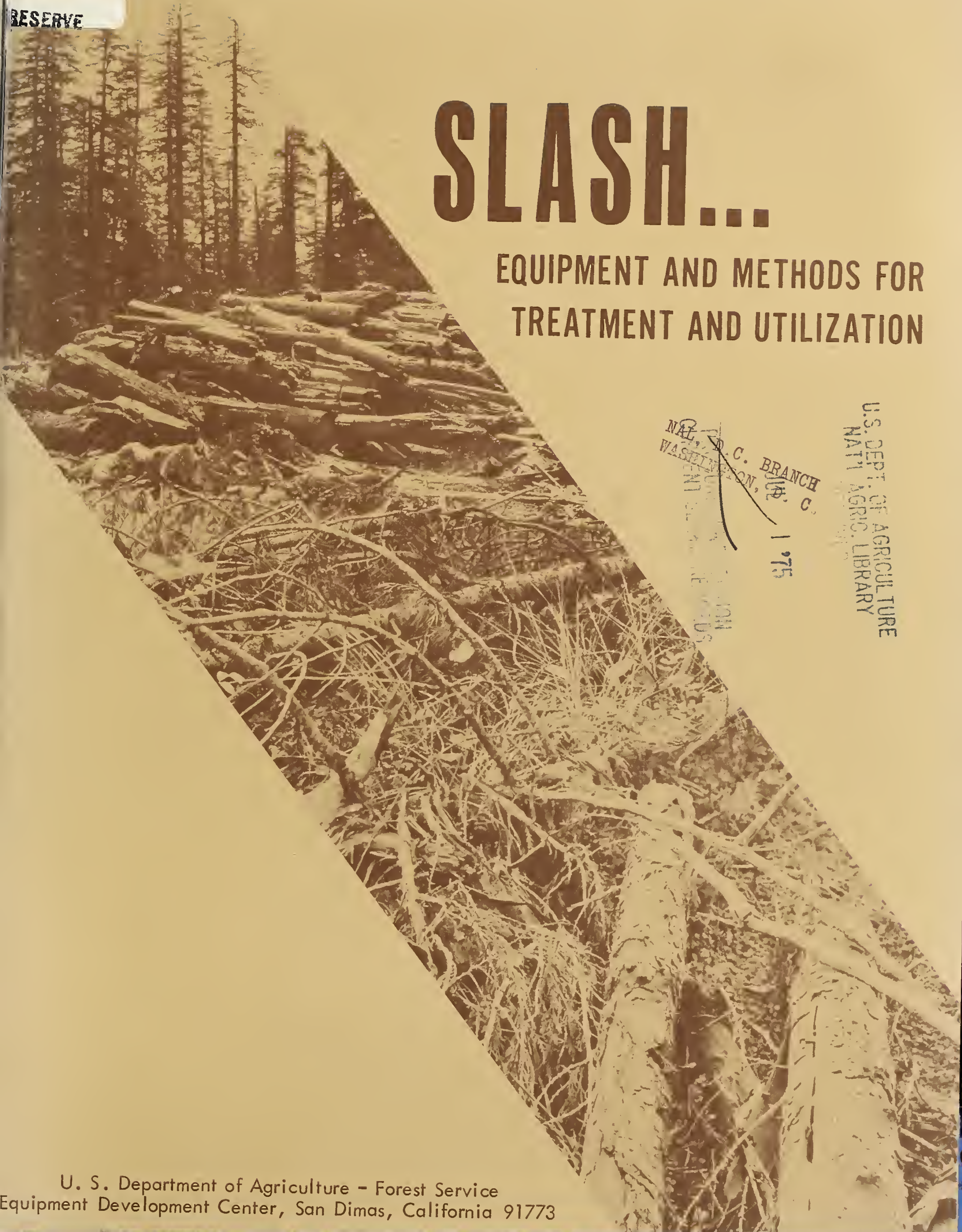

SLASH...

EQUIPMENT AND METHODS FOR TREATMENT AND UTILIZATION

U. S. Department of Agriculture - Forest Service
Equipment Development Center, San Dimas, California 91773

EQUIPMENT DEVELOPMENT AND TEST REPORT 7120-7

SLASH...

EQUIPMENT AND METHODS FOR TREATMENT AND UTILIZATION

by

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This report covers the following projects:

ED&T 2014—Logging Slash Treatment
ED&T 2158—Road Construction Slash Treatment
ED&T 2272—Timber Stand Improvement Slash Treatment

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ABSTRACT

Forest Service engineering personnel at the Equipment Development Center, San Dimas, California, have been working on equipment and methods for the treatment and utilization of forest residue, called slash, which is created by logging operations, forest road construction, and thinning of timber stands. First they defined the slash problem, then determined criteria for its solution, and finally investigated possible equipment and methods for treating the smaller, unsalable slash material and for processing the larger, heavy material for utilization.

Generally, it was found that existing mechanical equipment does not adequately treat slash. Thus, some basic engineering parameters are being investigated in a slash cutting test facility to generate design specifications for a device that will simultaneously thin young timber stands and treat the resulting slash. It is expected that this machine will also be suitable for the treatment of much of the 6-in and smaller logging slash, once larger material has been removed and utilized. Also, it appears that the best treatment for the unusable portion of heavy slash is air curtain burning.

KEY WORDS: Slash, slash treatment, slash reduction, slash burning, air curtain burning, forest residue, slash utilization, chipping machines, compacting machines, stump splitters.

INTRODUCTION

This report, summarized in the section that follows, contains information on the on-going projects at the San Dimas Equipment Development Center (SDEDC) pertaining to slash treatment and utilization. (These two terms are defined in the Summary section.) Comprehensive slash projects began in 1969 as our engineers evaluated, observed, or otherwise learned of existing equipment and methods for dealing with the slash problem.1/ This many faceted problem is discussed in the section that follows the Summary and presents what is slash, where does it come from, why it is a concern, and several pertinent aspects of slash problem solution. The three report sections that follow this Problem and Possible Solutions section are devoted to a thorough presentation of what was found, seen and determined—based on either evaluation, observation, interview, or information search.

These three sections—Mechanical Equipment, Slash Burning, and Other Slash Treatments—detail how slash has been dealt with and what results have been obtained. They comprise the main body of the report and present all that has been so far discovered—whether (a) just some factual material on an approach to the slash problem learned from literature search and, perhaps, interviews with either field personnel who had seen or used the proposed equipment or with industrial personnel who had designed and were trying to sell the equipment; or (b) at the other extreme, definitive data obtained during a planned test program where the equipment or method was used and determinations were made by measurements and by observations of personnel knowledgeable in fire and timber management, etc. The report then has a section containing Conclusions and Recommendations based on work to date; i.e., through the first quarter of CY '74.

Additional reports on the slash projects at SDEDC will be forthcoming and will present current and future work with any new conclusions and recommendations resulting therefrom.

1/ Some slash effort at the SDEDC dates back to 1963; thus, pertinent work prior to 1969 is also documented in this report.

SUMMARY

Personnel at the San Dimas Equipment Development Center (SDEDC) have been intensively investigating equipment and methods for the treatment and utilization of slash since 1969, with some effort predating even this. Slash is the residue left in the forest after timber has been cut or roads constructed or trees thinned out. That is, slash consists of tree tops and limbs, cull logs, and stumps or root wads that are left lying around on the forest floor after logging, clearing, grubbing, and thinning operations. This slash material can cause all sorts of problems:

- Creates fire hazard
- Impedes further silvicultural activities
- Produces unaesthetic appearance
- Adversely affects watersheds
- Fosters insects and disease
- Impairs wildlife and livestock movement.

Slash treatment consists of physically operating on the forest residue by doing one of the following: crushing, cutting, chopping, chipping, splitting, burning, burying, or (in the extreme) removing so as to render the particle size and arrangement of the slash less objectionable as judged by knowledgeable professionals. Slash reduction occurs when, in one of the preceding operations, the total center of gravity of the slash is lowered with respect to its elevation above the ground.

Slash utilization occurs whenever the wood fiber in the slash material that has been treated ends up in a usable form such as chips, particles, or flakes that can then be used in paper-making and fiberboard manufacture.

The San Dimas slash effort began by investigating existing treatment methods and attempting to measure their effectiveness. Over the years about 50 different pieces of equipment that have the potential to mechanically reduce slash and then, perhaps, produce usable forms of wood fiber have been field evaluated, or investigated through observations and interviews, or reviewed by literature search and salesman briefings.

In addition to this work on crushers, choppers, cutters, chippers, flails, hammermills, and splitters; devices for the controlled burning of slash were also investigated. Finally, other "exotic" approaches to slash treatment were searched out—including exportation, burying, explosives, and biological control.

The criteria for evaluating the mechanical reduction equipment were to find devices that would efficiently, effectively, and economically break up and compact the small, flashy aerial material (foliage, bark, small limbs, and twigs) to lower the fire hazard and provide an optimum amount of natural nutrients for decomposition as an aid to forest regeneration.

When it came to evaluating machinery as utilization devices, the criteria were how efficiently, effectively, and economically these machines could handle and convert slash material into forms that could be used in mills. We were looking for the production of chips, flakes, or particles of specified size, shape, and freedom from "foreign material" (i.e. bark, dirt, char, and rot).

Not surprisingly, the mechanical treatment and utilization equipment studied proved less than ideal for the job at hand since most were not originally designed to work in the forest and handle slash material. This is not surprising because adequate design information was not available. As this became apparent, activity got underway to establish a slash cutting test facility at the SDEDC so Forest Service engineers and technicians could generate the basic data needed to design an efficient treatment tool. We wished to design a device to simultaneously thin young timber stands and treat the resulting slash. This work to determine the optimum mechanical cutting device and its energy requirement is about complete and the final specification for a machine that can simultaneously thin trees and treat slash will soon be available.

This machine should also be suitable for the treatment of much of the 6-in and smaller slash left by logging operations—once large logging and road construction residues have been removed and utilized. For the latter, a number of stump splitting and removing devices have been studied. Also, it appears that the best approach to the unusable portion of heavy slash from logging or road construction activities is air curtain burning.

This is an efficient, non-polluting method of controlled incineration for unusable slash material. Specialized burning equipment is used to produce relatively smokeless burning at temperatures over 1,600°F. Forced air, traveling at 100 mph, supplies oxygen for intense combustion and drives volatile gases into an air curtain where secondary combustion takes place—resulting in a complete, no-smoke burn.

To present what has so far been learned about the various slash treatment and utilization equipment and methods, tables 1, 2, and 3 have been prepared for each of the three primary activities that create slash. Each type of equipment or method was placed in the table(s) where it was felt it would prove to be useful. Some approaches have little application for any type of slash and, thus, are not included in these tables. The following is an indication of what is presented under each table heading:

Equipment or Method—Designation of treatment or utilization approach that was investigated

Slope Limitation — A qualitative measurement, based on observed working (not maximum) performance on firm soils

Size Limitation— Diameter of slash material that can be treated

Cost, including Support Equipment— Includes all known costs, fixed and maintenance, move in and out, and necessary personnel

Point-of-View Acceptability — Judgment values designating, by numbers, the acceptability of the listed treatment from various Forest Service management standpoints—the highest degree of excellence is signified by a "1" with each larger number (2, 3, etc.) signifying lower rankings (see the appendix for detailed explanations of these ratings)

Suitable Areas for Treatment — Judgment value of where treatment might be used to advantage

Table 1. Treating and utilizing logging slash

Equipment or Method	Slope limitation (%)	Size limitation: Diameter (in)	Size limitation: Length (ft)	Cost, including support equipment ($/ton)	Point-of-View Acceptability: Aesthetics	Watershed	Fire Mgt.	Timber Mgt.	Engineering	Suitable areas for treatment	Support equipment needed	Most notable shortcomings	Most notable advantages
Tractor crushing	30	4 to 6	None	3.50	3	2	3	3	2	Not recommended	None	Very inefficient	None
Young Tomahawk & ATECO Compactor	30	4 to 6	None	3.10	2	2	2	2	2	Any, within size & slope limitations	Tractor, D6 or larger	Marginal results - treats only brittle material on hard ground	None
Towed Rolling Choppers	20	4 to 8	None	6.80	3	3	2	3	4	Southeastern U.S.	Tractor, D6 or larger	Sensitive to rocks—blades break; treats only soft species	None
Morbark Chiparvestor & Precision Tree Harvester	Limit of skidders	22	None	3.30 (chipping only) 10.00 2/ (total)	1	2	1	1	3	Clear cuts	Truck-tractor, tractor, feller-buncher, & grapple skidders	Large initial investment; must be market for total chips	Very high quality treatment; provides "clean logging"
Nicholson Ecolo Chipper	Limit of skidders	24	None	?	1	2	1	2	3	Any, within size & slope limitations	Grapple skidder	Large initial investment	Very high quality treatment
Tree Eater	20	10	None	?	1	2	1	1	4	Any, within size & slope limitations	None	High down time	Thorough treatment
Wagner-Bartlett Stump Splitter-Remover	Limit of loader	96	None	$3.50/stump	NA 4/	NA	NA	1	1	Any, within size & slope limitations	Loader	Treats stumps only	Best currently available stump treatment tool
Broadcast Burning	None	About 4 1/	None	4.10 3/	5	4	2	4	1	Any	Full fire protection	Incomplete treatment; soil damage; air pollution; high fire escape danger	Inexpensive in terms of area treated ($70/acre)
Pile Burning	30 (Limit of piling tractor)	About 6 1/	None	4.00 3/	4	3	2	3	1	Any, within size & slope limitations	Fire protection	Essentially same as broadcast burning	Simple and easy
DriAll Air Curtain Destructor	Limit of yarding method	96	Length of pit	5.70	1	2	2	2	2	Stable soil	Crane, backhoe	Only for large quantity of unusable material	High quality job; longer burn season than pile burns
Comron Air Curtain Combustion Unit	Limit of yarding method	48	20	8.00	1	1	3	2	3	Any	Truck-tractor	Large initial expense; danger of spot fires	High quality job; longer burn season than pile burns; mobile, no pit needed
Exportation	Limit of yarding method	None	None	?	1	3	1	2	2	Any	Tractor, D8 or larger; stump splitters/removers	Disposal can be impractical	Can lead to utilization
Burying in Cells	30 (Limit of piling tractor)	None	None	3.80	2	4	1	5	1	Areas needing intensive cleanup	Tractors, D4 for piling & pushing; D8 for digging	Removes area from timber production	Hides slash from view

1/ Depends on burning conditions.

2/ Based upon 75 ton/acre lodgepole pine; total slash reduction show—does not include road costs, loading, or hauling chips from site, and does not allow any credit for possible sale of chips (8).

3/ Based upon 140 ton/acre old-growth Douglas-fir logging slash.

4/ Not applicable.

Table 2. Treating and utilizing road construction slash

Equipment or Method	Slope limitation (%)	Size limitation: Diameter (in)	Size limitation: Length (ft)	Cost, including support equipment ($/ton)	Point-of-View Acceptability: Aesthetics	Point-of-View Acceptability: Watershed	Point-of-View Acceptability: Fire Mgt.	Point-of-View Acceptability: Engineering	Suitable areas for treatment	Support equipment needed	Most notable shortcomings	Most notable advantages
Nicholson Ecolo Chipper	Must work from road	24	None	?	2	2	2	3	Any, within size & slope limitations	Grapple skidder	Large initial investment	High quality job
Vermeer 671 Log Chipper	20	30	6	10.00	1	2	2	3	Accessible areas needing intensive cleanup	Tractor, with brush rake & a loader	Applicable only for intense cleanup in landscape mgmt. zones	None
Ray Ecological Demolisher	Must work from road	96	25	?	2	2	2	4	Any, within slope limitation	Crane	Huge initial investment	High quality job
Wagner-Bartlett Stump Splitter-Remover	Limit of loader	96	None	$3.50/stump	NA 2/	NA	NA	1	Any, within size & slope limitations	Loader	Treats stumps only	Best currently available stump treatment tool
Pemco Cable Cruncher	Must work from road	30	None	1.15	3	2	3	2	Any, within size & slope limitations	Crane, 20-ton or larger	Limited to piled slash	None
Pile Burning	Limit of yarding method	About 6 1/	None	4.00	4	3	2	1	Any	Tractor w/rake; fire protection	Incomplete treatment; weather dependent; air pollution	Simple and easy
DriAll Air Curtain Destructor	Limit of yarding method	96	Length of pit	5.70	1	2	1	2	Stable soil	Crane; backhoe	Only for large quantity of unusable material	High quality job; longer burn season than pile burning
Camran Air Curtain Combustion Unit	Limit of yarding method	48	20	8.00	1	1	1	3	Any	Truck-tractor	Large initial expense	High quality job; longer burn season than pile burning; mobile, no pit needed
Exportation	Limit of yarding method	None	None	?	1	3	1	2	Any	Tractor, D8 or larger; stump splitters/removers	Disposal can be impractical	Can lead to utilization
Burying in toe of fill	Limit of yarding method	None	None	4.30	1	2	2	1	Fill area	None	Possibility of degrading road quality, if improperly used	Simple and non-polluting

1/ Depends on burning conditions.
2/ Not applicable.

Table 3. Treating and utilizing TSI slash

Equipment or Method	Slape limitatian (%)	Size limitatian		Cost, including suppart equipment 1/ ($/ton)@(tan/hr)	Paint-of-View Acceptability					Suitable areas for treatment	Suppart equipment needed	Simul-taneaus thinning and treatment	Mast natable shartcamings	Mast natable advantages
		Diameter (in)	Length (ft)		Aesthetics	Watershed	Fire Mgt.	Timber Mgt.	Engineering					
Tractar crushing	30	4 to 6	Nane	0.80 @24	4	3	3	3	2	Not recammended	Nane	Na	Very inefficient	Same breaking and campacting accamplished
Yaung Tomahawk & ATECO Cam-pactor	30	4	Nane	0.70 @32	3	3	2	2	2	Western U.S.	Tractar, D6 ar larger	Yes	Slaw & not taa efficient - needs hard graund and brittle material	Gaad results with small, dry material
Towed Ralling Chappers	15	4 to 8	None	1.60 @24	3	3	2	2	4	Relatively flat, "easy" cauntry	Tractar, D6 or larger	Yes	Sensitive to rocks-blades break; damages leave trees	Gaad results with small-stem material
Natianal Hydro-Ax	30	6	Nane	2.00 @24	2	2	1	2	3	Any, within size & slape limitatians	Nane	Yes	Leaves sharp stubble which can damage tires & tracks	Most tharough treatment
Kershaw Klear-way	25	6	None	2.00 @24	2	2	1	2	3	Any, within size & slope limitatians	Nane	Yes	Leaves sharp stubble which can damage tires & tracks	Mast tharough treatment
Trakmac/ Trailmaker	35	18	None	6.50 @7	3	2	1	3	4	Any, within size & slope limitatians	Nane	Yes	High dawn time	Law graund pressure
Tree Eater	20	10	Nane	2.50 @32	1	3	1	1	5	Any, within size & slape limitatians	None	Yes	Undependable; damages leave trees	Tharough treatment

1/ Based upan 40 tan/acre heavy precammercial thinning trees up ta 8-in dbh-panderosa and lodgepale pine, and mixed stands of fir larch and hemlock (1, 2, 7).

Support Equipment Needed—Companion machinery and equipment needed to provide a working system for maximum possible slash treatment

Simultaneous Thinning & Treatment—In TSI slash only (table 3), an appraisal of whether the equipment or method has the potential to do both in a strip-thinning effort

Most Notable Shortcomings — Likely field-use problems with listed slash treatment or utilization approach

Most Notable Advantages — Outstanding qualities or features of listed approach

It should be recognized that the ratings under "Point-of-View Acceptability" and the comments appearing in the three tables are nominal. Local conditions and associated factors can alter the "results" presented; judgment must be applied in attempting to use the tables and the extensive report that follows this section in decision-making activities.

SLASH - THE PROBLEM AND POSSIBLE SOLUTIONS

Scope of the Problem

The Forest Service manages 187-million acres of land, or over 8 percent of the total area of the 50 states. Timber is one of the primary resources produced on National Forest land. Current timber management policy is to pursue a high level of productivity while enhancing the quality of the environment. Our foresters, wildlife biologists, hydrologists, soil scientists, engineers, and landscape architects all contribute to determining how maximum timber can be harvested while still improving forest ecology. A large challenge to be met is what to do with the slash that is created in the course of managing the timber resource.

For instance, in Washington, Oregon, and California in 1969, the volume of residue created by logging operations was just over 1-billion cu ft, which is 29 percent of the volume harvested and sent to the mills (9). As the Chief of the Forest Service recently stated (12):

"Potential for closer utilization of available timber supplies [is] indicated, in a general way, by inventory volumes that are left as logging residues after completion of timber harvesting. The large volume of such residues on National Forest cutovers has long been a serious problem—in terms of wasted material, costs and dangers of slash disposal, and difficulties in obtaining regeneration.

"Much progress was made in the 1970-73 period in the utilization of National Forest timber harvests as a result of rising timber values and new contract requirements for closer utilization in National Forest timber sales. . . Nevertheless, sizable volumes of timber are still left as logging residues."

Causes of the Problem

The three types of slash under consideration are logging slash, road construction slash, and timber stand improvement (TSI) slash. Logging slash is that residue left after a harvest operation, and includes the foliage and branches as well as stems and cull logs. Road construction slash includes all of the elements of logging slash plus stumps and root wads which must be cleared from the right-of-way. The partial burial of slash during road construction pioneer work further complicates the problem. TSI slash consists of foliage and stems left after precommercial thinning operations.

Quoting Olsen and Fahnestock (14), "To grow, a tree must have foliage, and foliage requires branches for its support. When harvested, the crown which has been all important to the living tree becomes a liability. Branches and limby top must be removed from the usable portion of the tree and left in the forest where they become a fire hazard, hinder forest operations in the woods, and detract from the beauty of the forest. Additional debris accumulates in a normal logging operation from the snags, defective trees, ...and from the accidental "pushover" and breakage in felling and

Figure 1. Logging slash.

skidding operations–all of this is logging slash. It is an inescapable result of timber harvesting that creates a complex problem in the management of forest land." In addition to logging slash, a great volume of presently unutilized or unmerchantable material is created during the right-of-way clearing and construction of forests roads and highways, and during TSI operations, such as hand or strip thinning.

Logging Slash

Logging slash presents two problems–brush, limbs, and tops; and cull logs. Figure 1 is a view of typical brushy material left by a logging operation in the Pacific Northwest. This slash is characterized by its size, generally less than 4-in maximum diameter, and by its features, a great deal of needles and very fine twigs. When left in place, it will normally present a serious fire hazard within 2 or 3 weeks after cutting (14).

Cull logs (fig. 2) make up a significant portion of the logging slash. These logs which could probably be utilized for chipping but are less than one-third utilizable as saw logs. This pile was found on the Mt. Hood National Forest and is not unusual on old-growth Douglas-fir logging sites. Often slash in clear cut areas is burned and all of the light fuels go up in flames, but the cull logs remain. A system is needed to economically utilize these logs instead of attempting to burn them in place. Increasingly, loggers are required to remove all logs from a sale–often referred to as Yarding of Unmerchantable Material or YUM logging. Some of the piles of cull logs at landings in the Northwest contain as much as 2 million board feet.

Road Construction Slash

Road construction slash contains all of the elements of logging slash and indeed is quite similar

Figure 2. Cull logs.

in many respects, since merchantable timber is sold from road rights-of-way. However, road construction slash inevitably also contains stumps and root wads, which may have a great deal of in-grown rocks and dirt (fig. 3).

TSI Slash

TSI slash results from the thinning of a timber stand to accelerate growth and enhance wood quality. This slash generally falls into two cate-

Figure 3. Roadside construction slash.

Figure 4. Hand-thinned TSI slash.

gories; hand-thinned and strip-thinned slash. Figure 4 shows a hand-thinned area.

The hand-thinning technique generally used is on a 1-man, 1-saw, 1-tree basis; after the leave-trees are selected, the remainder are removed with a chain saw or are chemically thinned. Because no access is provided for equipment, it is difficult to treat hand-thinned slash without damaging the leave trees. In strip (or row) thinning, entire strips of trees are removed mechanically with specially equipped tractors. However, as in hand thinning, there is no slash treatment.

Effects of the Problem

Each of the three types of slash adversely affects many areas of forest management; the lessening of these adverse effects is the reason for slash treatment. Perhaps the most often mentioned is that slash presents a serious fire hazard. Also, slash interferes with access and management of the area for reforestation, stand improvement, and future harvesting operations.

Fire Danger

The high danger of fire in slash is well documented for all three types of slash (3, 5, 7). Fire hazard is considerably lowered as slash decomposition is accelerated. Slash is more rapidly decomposed as its size is reduced, and as it is compacted to the ground. Branches left uncompacted will tend to become hard and decompose very slowly until they are brought in close contact to the ground. Slash from many of the pine species will hold needles for several years, causing an extreme fire hazard.

Aesthetics

The appearance of waste and dead material at a logging site should be avoided. Even after burning slash, via broadcast or pile burning, the burned areas are displeasing for a period of a year or more. Also, even if not considered a health hazard, the side effects produced by fire, such as vast quantities of smoke, are aesthetically displeasing. The problem of aesthetics is not just how a scene is viewed by Forest Service personnel; the reaction of the general public must also be considered. The public

tends to view heavy slash, cull logs in particular, as an ugly example of waste and bad management. The aesthetic appearance of the forest, following logging and road construction operations, is an important management consideration.

Watershed

The effect of slash concentrations on watershed is not well defined. Certainly any practice which allows accelerated erosion would be inimical to water quality. Cull logs and other road construction debris are not permitted in stream channels or waterways.

Insects and Disease

Insects and disease organisms inhabit slash, and can spread to healthy stands. Bark beetles, wood rot, and white pine blister rust are all suspected to be possible side effects of slash concentrations.

Large Animal Movement

Slash concentrations can impede large animals; both domestic and game animals are affected. In range reclamation areas, slash disposal equipment may be used to remove or treat scrub trees and brush.

Criteria for Problem Solution

The long-term Forest Service goal in the area of slash is not to create any; i.e., to utilize the whole tree, leaving on the ground only an amount and type of material deemed beneficial to regeneration and local plant and animal life. Efforts now underway to take more and more forest residue created by timber and road activities, and to size and clean the slash material for chipping, are directed at producing a maximum quantity of wood chips, flakes, and particles. These can then be used to make pulp or particleboard. As demand for paper and structural lumber increases in this country, there will be a corresponding increase in the demand for usable forest residue.

Developing criteria for treating slash presently on the ground was difficult because specialists in various fields have differing views as to priorities. For instance, a fire manager looks at the slash problem differently than a silviculturalist. Treatment costs and available funding also had to be considered when establishing program goals. In general terms, the immediate goal we established in slash treatment was the elimination of aerial fuels, leaving residues that would not interfere with firefighting or other forest management objectives.

The criteria for a successful approach to the slash problem are unique with each situation. An approach to be considered successful in logging slash should look toward using cull logs with remaining tree crowns, limbs, and small stems treated in such a manner as to minimize fire hazard (rate of spread and intensity). This approach should also leave slash in such an arrangement as to allow fire lines to be readily built by hand or with equipment, and to allow for site preparation and tree planting.

The basic approach for road construction slash is essentially the same as for logging slash. Additionally, methods should be considered for treating residues which cannot be left along the road because of the potential fire hazard.

TSI treatment should thin the stand and treat slash in a single operation. Any thinning method that does not allow access for mechanical treatment should be rejected.

All methods of treatment and utilization should minimize erosion and other negative environmental impacts, and should leave the site aesthetically acceptable and in condition for economical management.

Broadcast burning, one of the most widely used slash treatment methods, can leave an unacceptable amount of residue on the ground and can cause air pollution. That is why engineers at the SDEDC began to seek alternative approaches to the slash problem. Our investigation of equipment and methods for treating slash was guided by the following criteria:

1. Residue left: must be of a size, form, and arrangement to
    - Minimize the fire hazard and allow for fireline construction without the aid of a chain saw
    - Provide for new growth on the site
    - Permit future operations, as machine planting and logging

- Present an acceptable appearance

2. Environmental effects—forest floor disruption, air pollution, water pollution, etc., must be minimized

3. Cost—any slash reduction method must not be so costly as to preclude its widespread use

Each of the three types of slash to be treated (logging, road construction, and TSI) will probably require unique treatment machinery and methods; however, some equipment might prove successful on more than one type.

Approaches to Problem Solution

Over the years, personnel at the SDEDC have taken the following approaches to solving the slash problem, making cost comparisons, wherever possible, and also attempting to consider ecological and aesthetic impacts:

1. Evaluate mechanical equipment:
   a. Observe and gather data on existing machines
   b. Investigate engineering characteristics of all types of mechanical cutters which are being used, or could possibly be used, in treatment and utilization of slash

2. Investigate burning methods:

3. Gather data on other treatment methods (exportation, burying, explosives, etc.).

This report documents progress to date (first quarter, CY '74) and presents in-depth observations on investigated equipment and methods for slash treatment and utilization.

Summary of Progress in Problem Solution

Our engineers and technicians have been pursuing answers to the slash question for over 10 years now. Approximately 50 different pieces of mechanical equipment have been investigated and the "clean burning" of slash using air curtain burners has been demonstrated. A unique test facility has been set up at the SDEDC to investigate basic force and power parameters encountered when chipping wood with heavy equipment. We have been investigating cutters of various sharpness, including cutters with dull blades, and have generated significant new design data for both blade and flail cutters.

Work by many forest researchers seems to indicate that the largest amount of nutrients and soil conditioners are contained in a tree's foliage, bark, and stems. Silviculturalists also tell us that for successful regeneration of many tree species some on-the-ground residue or litter is required. All of this fits in nicely with the methods proposed as a result of the SDEDC slash treatment evaluations. They are:

- Treat foliage, branches, and stems, and leave unusable material as litter on the forest floor

- Utilize wood from stems that are 3- to 6-in in diameter, depending on market conditions

- Burn with minimum emissions unsalable large material, such as root wads and cull logs, until methods can be developed to utilize them

All-in-all, fairly good mechanical treatment of slash has been limited to aerial fuels and small stems. At this time it appears we will have to depend on utilization to dispose of heavy materials. Until this can be achieved, clean burning is suggested as one of the best alternative solutions.

MECHANICAL EQUIPMENT

A large variety of mechanical equipment for the treatment or utilization of slash has been investigated and tested, including crushers, choppers, cutters, and chippers, plus flails and hammermills. This equipment is used to break up and compact the small, flashy aerial material (foliage, bark, small limbs, and twigs) to reduce the fire hazard and to provide the most beneficial amount of natural nutrients for decomposition as an aid in forest regeneration, and to produce usable chips out of the larger limbs, cull logs, stumps, and root wads.

Not surprisingly, the machines checked out so far have proven less than ideal, as most were not originally designed for slash treatment and engineering test data on what was needed to treat slash was

not available. Thus, the Forest Service has begun an engineering development program in its slash cutting test facility at San Dimas, Calif., to determine the optimum mechanical cutting device and its energy requirement. From this we hope to develop specifications for a machine that will both thin trees and treat the TSI slash, as well as treat the smaller components of logging and road construction slash.

Tractor Crushing

The crawler tractor has been the most common piece of equipment used to reduce slash volume. The tractor is repeatedly maneuvered over the slash; the tracks and grousers break stems and branches, compacting the slash closer to the ground. The tractor is inefficient as a crushing device because the narrow width of the tracks requires many passes for satisfactory treatment. Also, the tractor treads tend to up-end and expose portions of slash material already buried within the compacted mass created by earlier passes of the tractor.

In tests we conducted, aerial fuels were reduced 1/ 46 percent in an area treated by a D6 tractor. And, as judged by a team of Forest Service professionals, fire hazard rating was reduced from HM to MM.2/

In general, tractor crushing inadequately reduces aerial fuel, leaves the treated site in a marginal condition aesthetically, and might inflict damage to fragile soils if complete treatment is attempted. On the other hand, tractor crushing appears to have some merit, though not as great as most other approaches, in pretreating green slash prior to broadcast burning. Tractor treating of green material hastens drying, contributing to a cleaner burn.

Cutter-Crusher Compactors (Young Tomahawk and ATECO)

Two firms offer segmented rollers having cutters and crusher teeth intended primarily for breaking up asphalt during road reconstruction work. These cutter-crusher compactors come equipped with universal mounting brackets for attachment to graders or dozers. Thus, the compactors can be mounted on a prime mover's dozer blade or in the rear. The Young Corp., Seattle, Wash., and the American Tractor Equipment Corp. (ATECO), Oakland, Calif., manufacture the compactors, which come in various widths, including 3, 6, and 9 ft.

The Young Corp. device, called the Tomahawk, comes in two designs. The standard model for roadbed work is made up of 21-in diameter rings; each ring has 8 circular longitudinal cutters for spacing and splitting, and 16 diagonal crusher teeth for crushing, sizing, and compacting. A high-profile model for brush/slash work has 24-in rings; the cutters protrude 2.5-in above the crushers instead of 1-in above, as in the standard model. The 6-ft wide high-profile model weighs 2,740 lb.

The ATECO compactor is similar to the Tomahawk standard model, except the half-round cutters do not protrude beyond the crushers. In 1971, extensive tests were run on the Colville National Forest, in Eastern Washington, using a 6-ft-wide rear-mounted ATECO unit (fig. 5) and both a front- (fig. 6) and rear-mounted 6-ft-wide high-profile Tomahawk with D6 and D7 tractors. In addition, a special forestry model Tomahawk, consisting of two 3-ft-wide high-profile sections side-by-side, with their center shafts 16° out of line with each other (fig. 7) was rear mounted and tested.

Tests on the four configurations were conducted in TSI slash—both hand (chain saw) and strip (bulldozer) thinned—and in logging slash. Besides using the Tomahawks as supplied, additional weights were added during some test runs to determine if more down force would increase the effectiveness of slash treatment. The special forestry model was tested with added weights of 960, 1,680, and 2,400 lb; the rear-mounted high-profile model with 1,200 and 2,400 lb. The tractors were able to maneuver the compactors on stable, firm slopes up to 40 percent.

The effectiveness of the three different Tomahawks and the ATECO was about equal. All provided about the same amount of treatment as the grousers of a medium-sized crawler tractor. Neither the more expensive special forestry model nor the added-weight versions produced any better results. The biggest discrepancy was that the blade-mounted units suffered from failures in the

1/ Percent reductions in slash presented in this report are based on a "survey" method suggested by the work of Dell and Ward (5).

2/ Pacific Northwest Region (R-6) rating system (19): E = extreme, H = high, M = moderate, L = low; where the first letter identifies the rate of spread, the second resistance to control (e.g., HM, MM, etc.).

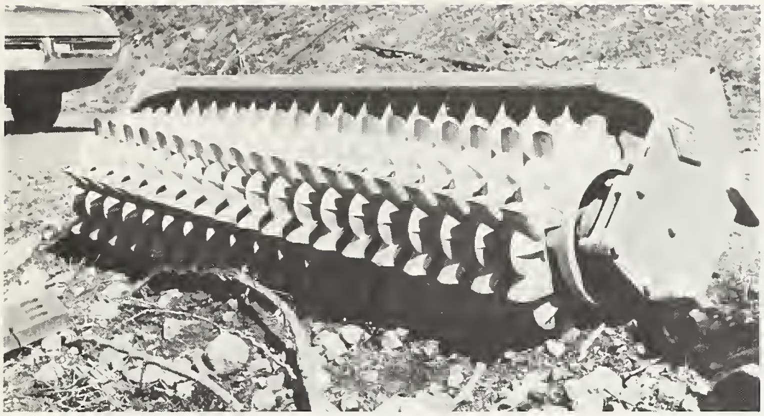
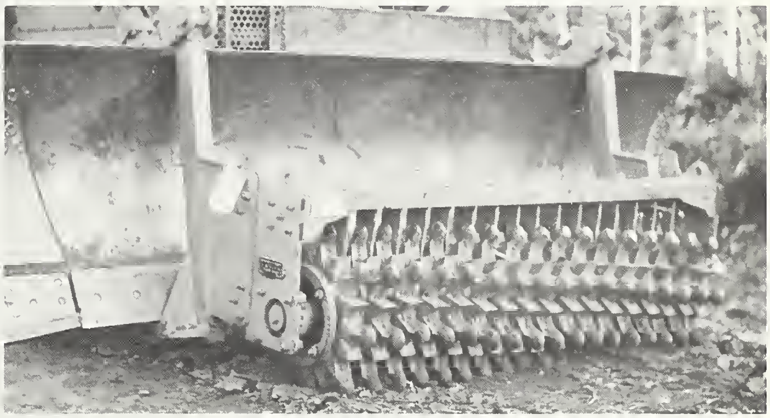


Figure 5. ATECO cutter-crusher compactor.

Figure 6. Blade-mounted, high-profile Tomahawk.



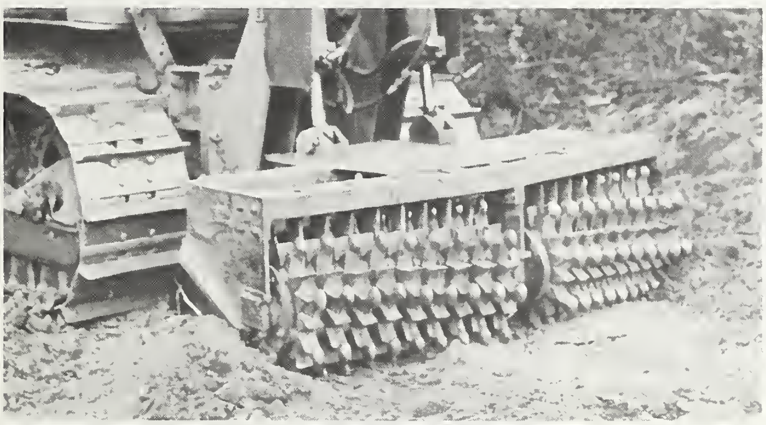


Figure 7. Special forestry model Tomahawk.

shaft bearing housings and the top, main frame bar was prone to bending.

The four configurations were more successful in reducing the TSI slash than logging slash. In both hand- and strip-thinned cedar, pine, and fir slash, stems of less than 4 in were fairly well broken. Bark was removed from larger pieces and slash was compacted to the ground. Thus, their most efficient use would be in precommercial thinning slash where the material is small and can be more easily broken and compacted. This is particularly true of dry, thinned material a year or more old.

In strip thinning, where simultaneous "take-tree pushover" and treatment was done, the compactor's benefit was limited to removing upright branches and compacting the finer materials to near ground level. Some bark was removed from

Figure 8. Treated strip-thinned TSI slash.

the boles. It took about 1.5 hr to work an acre of TSI slash.

In logging slash, effective treatment was limited to some limbs up to 6-in in diameter that were dry and in positions to break easily. Limbs and tops were broken and compacted where large material did not interfere, but overall results were marginal. This would also be true in road construction slash, except that no effective treatment could be expected for root wads and piles of residue along rights-of-way.

The four compactors reduced aerial material an average of 47 percent in TSI slash and 67 percent in logging slash. Fire hazard for treatment of thinning slash was reduced on an average from EE or HH to LM; but for logging slash the reduction was only slight, as judged by a team of professionals. Overall, these devices were no where near optimum, but they did reduce the fire hazard and improved the condition of the area. Figure 8 shows treated area after two passes by a rear-mounted Tomahawk.

Towed Rolling Choppers

A rolling chopper, pulled behind a crawler tractor, essentially is a roller with cutting blades mounted across it. Three Florida companies are the primary suppliers: Fleco Corp. (Jacksonville), Marden Manufacturing Co. (Auburndale), and Rockland Inc. (Winter Garden). The choppers come in three different cutting-blade configurations: straight (fig. 9), V-shaped or herring-bone (fig. 10), and angled.

Figure 9. Straight-blade rolling chopper.

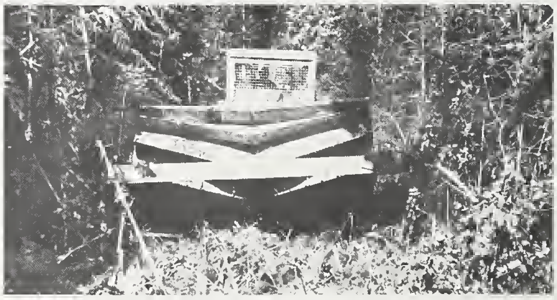


Figure 10. Herringbone-blade rolling chopper.

Rolling choppers also come in a variety of sizes, and most can be filled with water to increase weight. They have been used extensively in the Southeast for slash and brush treatment of small-stem material. The rolling choppers sever the stems into approximately 2-ft lengths.

We tested the Marden B7, towed behind a Caterpillar D8 tractor, on the Colville National Forest, Wash. This roller is 5-ft in diameter, including the blades, and weighs 24,000 lb when filled with water. The unit was pulled through an area of TSI slash. The test was conducted on slopes up to 15 percent only, since the operator felt the unit was unsafe on steeper areas. During test runs leave trees were excessively damaged, particularly on slopes and blade breakage was common (fig. 11). Nevertheless, the towed rolling choppers, no matter what blade configuration, are somewhat more effective than the four tested compactors.

Figure 11. Broken blades, Marden B7.

In addition to the field test, we had some laboratory tests conducted. These showed that the force required to shear slash of a given species doubles as blade condition progresses from new to fully worn. Further, for the species tested, it also takes twice as much force, on the average, to cut a stem when it's frozen (winter months) as when unfrozen. Cutting force increases as chopper speed increases, so choppers should be operated as fast as safely possible.

As to the actual mechanism involved in slash treatment with a rolling chopper, we feel that if the ground is hard enough, pure shear is the treatment mechanism. If the ground is soft, or if the slash is thick or matted, bending and breaking would necessarily be the mechanism. This is why, if the slash is too supple to break and the ground is too soft to be an effective anvil, little treatment can be expected.

Self-propelled Rolling Choppers

LeTourneau Tree Crusher

R. G. LeTourneau, Inc., Longview, Texas, produces a series of large self-propelled rolling choppers known as "Tree Crushers." These machines are expensive and heavy, weighing from 37 to 97 tons. A 40-ton model is shown in figure 12.

These units have a push bar in front for toppling trees. The bar is adjustable on some units to accommodate trees of varying size. Like the towed choppers, the blades on the self-propelled choppers sever stems into lengths of about 2 ft.

They have been used with great success in the Southwest for eradicating juniper stands for range reclamation. This experience indicates the machine can handle side slopes of only 20 percent and slopes of 35 percent (maximum) when traveling up or down hill. To be cost effective these machines must work parcels of more than 1,000 acres. Tree Crushers incur high move-in/move-out costs as they must be dismantled, then reassembled for each site change.

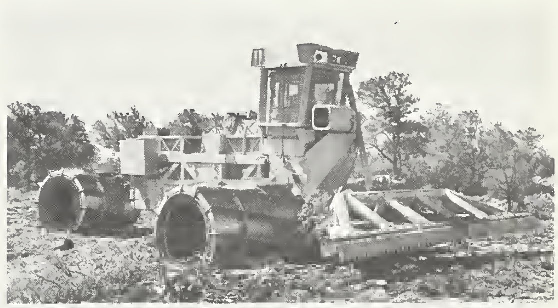


Figure 12. LeTourneau Tree Crusher.

Pettibone and Marden

Two other firms offer self-propelled rolling choppers: Pettibone Corp., Chicago, Ill., and Marden Manufacturing Co. (which makes the previously discussed model B7 for towing). The Pettibone unit (fig. 13) is self-powered, but is designed to be hitched to the front of a tractor. The engine, mounted on the chopper, powers the drum and

relieves some of the load on the tractor. According to the manufacturer, slope ability and maneuverability are greatly improved over nonpowered choppers.

The Marden PB7 self-propelled rolling chopper weighs 36,800 lb when full of water and makes a 7-ft wide cut as it traverses an area.

Figure 13. Pettibone self-propelled rolling chopper.

SDEDC personnel have not tested or even observed any of these machines in operation. Due to cost, size, and lack of maneuverability, self-propelled choppers are probably not the answer to slash treatment problems. This is the reason they are not included in tables 1 - 3.

Horizontal Shaft Cutters

We gathered comparative data on six horizontal shaft cutters:

- Madge Rotary Landbreaker, Madge Holdings Ltd., Calgary, Alberta
- Rotary Plow Model GMR 200 H, Rotary Plow Co. Ltd., Calgary, Alberta
- Shred-King 8000 FE, Triumph Machinery Co., Hackettstown, N. J.
- Nicolas Mulching Machine, Nicholson Manufacturing Co., Seattle, Wash., and National Hydro-Ax, Inc., Owatonna, Minn.
- Multi-Masta Model 52, Wilder Rainthorpe, John Wilder Ltd., Wallingford, Berkshire, England
- Yeomans Tritter Land Conditioner, Grasslands Party Ltd., Villawood, N.S.W., Australia.

An additional machine, the Tree Eater, could possibly be considered a horizontal shaft cutter. However, we have elected to discuss it under Flails and Hammermills later in this report.

Madge Rotary Landbreaker

Only one horizontal shaft cutter, the Madge Rotary Landbreaker, has been seen in action by the Forest Service. This occurred in 1971 when the timber staff officer on the Colville National Forest observed the unit being pulled by a D7 tractor through logging slash. It appeared capable of treating about an acre per hour at an estimated cost of $45. The observing forester felt the Landbreaker was "tough enough to chew up most slash in one pass . . . and was highly effective *under ideal conditions,* but would probably scar too many leave-trees for use in TSI slash and, further, would probably not handle 'large' logging slash."

Essentially the Landbreaker is a high-speed, heavy-duty Rototiller weighing about 20,000 lb and costing more than $31,000. It is 22.5-ft long, almost 10 ft wide, and has an enshrouded V-rotor that is 7.5-ft wide and 28-in in diameter, with 10-in slip-in, slip-out tines (flail-type cutters) of forged high-alloy steel. It is powered by a diesel engine of approximately 300 hp.

Rotary Plow

The Rotary Plow Model GMR 200H (fig. 14) is a towed, self-powered machine similar to the Land-

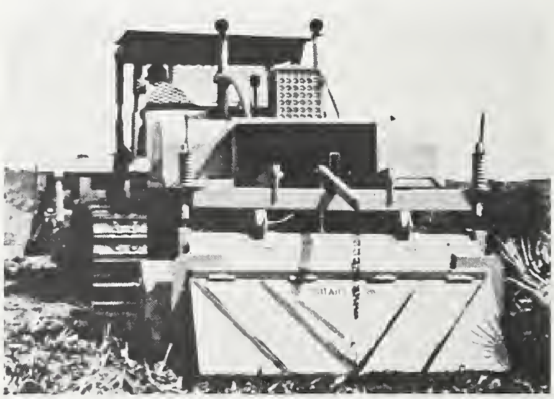


Figure 14. Rotary Plow.

breaker. The Rotary Plow weighs about 16,000 lb, costs more than $33,000, is 22.5-ft long, 9-ft wide, and comes with a choice of engines between 250 and 290 hp. Its enshrouded rotor consists of 12 fire-box steel plates, 20-in in diameter, drilled to accommodate six or eight 7- or 8-in long tines per plate. Over 360 of these machines are currently in use as farm and range preparation tools. Comments on the Landbreaker, already quoted, probably apply to the Rotary Plow.

Shred-King

The self-powered Shred-King 8000 FE mounts on the front of crawlers or dozers, weighs 5,800 lb, and can treat trees up to 6-in in diameter at a rate of 1.5 to 3 acres per day, according to its manufacturer. It has a diesel engine rated at 123 hp and a 5-ft wide cutting rotor, which consists of 20 steel discs that are 19-in in diameter.

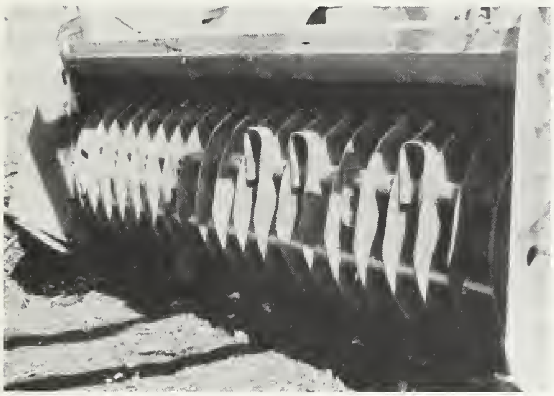


Figure 15. Shred-King rotor with "stirrup" cutters.

The machine's unique feature is its 38 stirrup-shaped, heat-treated alloy steel, double-edged cutters that slide quickly and easily on or off the rotor to be reversed, replaced, sharpened, or hard-surfaced. These cutters are arranged on four equally spaced shafts, providing a 100 percent cut across the full width of the swath. Each cutter swings freely between two discs, delivering 65,000 impacts per minute. Upon striking an impenetrable object like a rock, each cutting stirrup swings back on its shaft into the diameter of its neighboring discs, minimizing drive-train shock. Figure 15 shows three of the free-swinging cutters in the up position, the rest are down. It appears that this machine can do a better job than most in cutting slash material lengthwise or crosswise. This cutter has been tested in the SDEDC slash test facility.

Nicolas Mulching Machine

The Nicolas Mulching Machine comes in various sizes, and the manufacturer claims it effectively treats trees up to 5-in in diameter. The DT-213 model has a cutting width of 7.5 ft and requires, the manufacturer states, 140 hp; more horsepower is helpful. The unit weighs 4,000 lb and costs $9,000. The four rows of free-swinging flails contain 40 pivoted hammers. Figure 16 shows the DT-213 model mounted on a four-wheel-drive vehicle. The Model D100 cutter was tested in the Center's slash test facility in the early summer of 1974.

Figure 16. Nicolas Mulching Machine.

Multi-Masta and Yeomans Tritter Land Conditioner

The Multi-Masta and the Yeomans Tritter Land Conditioner appear to be too small for successful slash treatment. It is claimed that the Multi-Masta is capable of clearing scrub 20-ft tall and 4-in in diameter and of pulverizing logging "lop and top" up to 4-in in diameter. This machine (fig. 17)

Figure 17. Towed Multi-Masta.

costs about $1,500 and makes a 52-in cut with a 5.5-in diameter rotor having 16 pairs of heavy-duty flails. The Tritter Land Conditioner weighs 2,240 lb, is 122-in long, 84-in wide, and has a 5-ft rotor with 28 six-lb flails.

Vertical Shaft Cutters

We have observed four vertical shaft cutters as they treated slash in the field and recently ran tests on the cutting head of a fifth machine. The five machines are:

- Hydro-Ax, National Hydro-Ax, Inc., Owatonna, Minn.
- Klear-way, Kershaw Manufacturing Co., Inc., Montgomery, Ala.
- Trakmac/Trailmaker, Washington Iron Works, Seattle, Wash.
- Roanoke Robot Mountain Model, Harrington Manufacturing Co., Lewiston, N.C.
- Brush Cutter, Railway Maintenance Corp., Pittsburgh, Pa.

National Hydro-Ax and Kershaw Klear-way

These two machines (figs. 18,19) are similar, and both offer some promise in slash treatment. The Hydro-Ax was originally available from the Pettibone Corp., Chicago, as the "Master 550-B Hydro-Ax"; Kershaw at first called their unit the "Brushcutter." Both machines were developed basically for rights-of-way and land-clearing projects, and are self-powered and self-propelled. They have articulated steering and four-wheel drive for all-terrain use. Their power trains are hydraulic with hydrostatic transmission drives to the wheels. Both machines can suffer punctured tires if they must pass through high stubble. Their front-mounted rotating blades are enclosed in shrouds, permitting slash material to be finely chopped. Presently both come with fully enclosed cabs. The Hydro-Ax has a single vertical shaft making an 8-ft cut; the Klear-way two vertical shafts each making a 43.5-in cut.

Figure 18. National Hydro-Ax.

Figure 19. Kershaw Klear-way.

The Hydro-Ax model 500 pushes down brush and trees up to 5-in in diameter with a push bar that guides the slash material to the rotating cutter. Centrifugal force swings the two heavy 3/4-in steel blades out from a hub, forming an 8-ft cutting width of free-swinging, double-pivoted blades that give when hitting rocks and other impenetrable objects. The Klear-way model 10-3's flail-type blades are free-swinging and individually hinged. They can cut brush and trees up to 4-in in diameter. The machine's front-mounted twin rotors produce a 7¼-ft swath. Each rotor is individually powered and controlled; each is reversible. Comparative data on the two pieces of equipment are presented in table 4.

The Hydro-Ax was observed in 1972 on the Mt. Hood National Forest, Oreg., treating three specific areas. The machine successfully handled slopes of 30 percent. It treated 4 acres of green hand-thinned slash (predominantly Douglas-fir with some ponderosa pine and incense cedar) in 4 hours. The treated material had an estimated density of 3,500 stems per acre. A fire hazard

Table 4. Hydro-Ax and Klear-way Specifications

FEATURES	*Hydro-Ax*	*Klear-way*
Model designation	500	10-3
Cutting width (ft-in)	8-0	7-3
Overall height (ft-in)	9-0	8-9
width (ft-in)	8-0	7-8
length (ft-in)	25-0	21-8
ground clearance (ft-in)	1-5	1-5
wheelbase (ft-in)	9-0	8-9
Diesel engine (hp @ rated rpm)	125 @ 2,500	123 @ 2,500
Weight (lb)	19,800	15,000
Approximate cost ($)	48,000	42,000

reduction of EE to ML was achieved. Compared to work by cutter-crusher compactors in similar areas, the Hydro-Ax appeared to do a better job. Results compared to those obtained with the Tree Eater, a flail-type machine discussed later in this report.

Also treated was a similar 13-acre area of year-old, hand-thinned slash. It took 8.5 hours, and results looked equivalent to the treated 4-acre area of fresh slash. Fire hazard reduction was from HE to MM. Although the Hydro-Ax did not completely reduce all stems that were lying on the ground, they were compacted to within 6-in of the ground and all upright branches were removed. Remaining stumps were frayed, looking rather like chewed toothpicks, down to ground level.

Finally, simultaneous thinning and treatment was carried out in an 8-acre doghair Douglas-fir thicket where trees were up to 6-in in diameter and 15-ft high. Slopes were a maximum of 10 percent. It took the Hydro-Ax 8 hours. Results were better than obtained with cutter-crusher compactors, and almost no leave-trees were scarred.

Later in 1972, the Klear-way was seen operating on the Talladega National Forest, Ala., in a 3-acre area containing various hardwood species plus some pine. This material ranged from 500 to 1,200 stems per acre, 3- to 8-in in diameter, and had an average height of 10-ft. Simultaneous thinning and treatment was accomplished on slopes to 20 percent. The machine was an early preproduction model and had four blades per rotor. A later design was seen in action early in 1973 on the Sumter National Forest, S.C., on slopes up to 25 percent, as it cut overdense pine seedlings and saplings in TSI thinning. Stems up to 4-in in diameter were readily cut; the machine threw chips more than 200-ft in front and to either side when working in dense stands. Overall, the Klear-way produced results equivalent to the Hydro-Ax.

Trakmac/Trailmaker

The Trakmac, the prime mover, is a four-tracked, hydraulically driven, articulated vehicle (fig. 20). It features low ground pressure (under 4 psi) and travels in low range at speeds from 0 to 4.5 mph. The Trailmaker features a circular cutter that provides a 12-ft cutting swath. It is mounted on a swinging boom that has a lift of 4-ft. The manufacturer claims it can cope with standing material up to 10-in dbh, or chip 4-ft diameter stumps to ground level in less than 10 minutes. This device,

which costs about $40,000, was originally offered on the market as the Lucky Logger skidder with cutting "Wheel" by the Schetky Equipment Corp., Portland, Oreg. It was designed to clear log skidding trails with minimum damage to the forest floor. As now available, the all-terrain, hydrostatic-drive Trakmac has a diesel engine (123 hp @ 2,500 rpm), a heavy-duty enclosed canopy, and weighs 12,000 lb. Its overall length is 16 ft 5 in; height, 8 ft 4 in; width, 7 ft 9 in; ground clearance, 1 ft 5 in. The Trailmaker cutter weighs 4,000 lb and has a 36-in diameter cutter weighing 450 lb with a maximum rpm of 800.

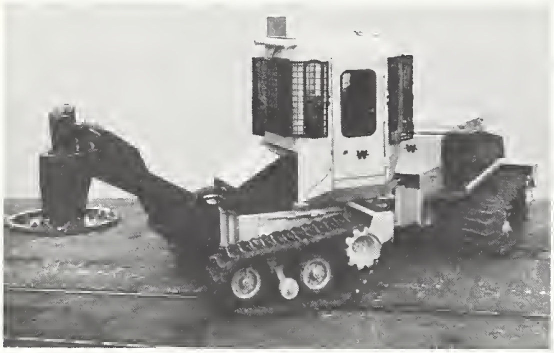


Figure 20. Trakmac/Trailmaker.

We observed the device in 1973 on the Deschutes National Forest, Oreg., as it thinned ponderosa pine and treated the slash. The cutting wheel is improved over original designs and now features bolt-in, easily replaceable teeth that cover the bottom, edge, and part of the top of the cutting wheel.

Late in 1970, the earlier Lucky Logger was demonstrated on the Mt. Hood National Forest. The cutting "Wheel" was seen treating logs, standing stumps, and small roadside slash. Figure 21 shows it reducing a large stump. The conversion of this 50-in diameter, 4-ft-high standing stump into chips down to the ground level took about 5 minutes. Unlike the Hydro-Ax and Klear-way machines, the Trakmac/Trailmaker does not have a shroud to restrain the material it is treating. So it cannot reduce a loose stump to chips because the stump will move away as the blade strikes.

The wheel had no difficulty, however, in reducing other slash material to chips, felling snags, or clearing a skidder trail. The demonstration was terminated when one tooth of the wheel struck a rock, broke off, and damage to the tooth holder could not be repaired in the field.

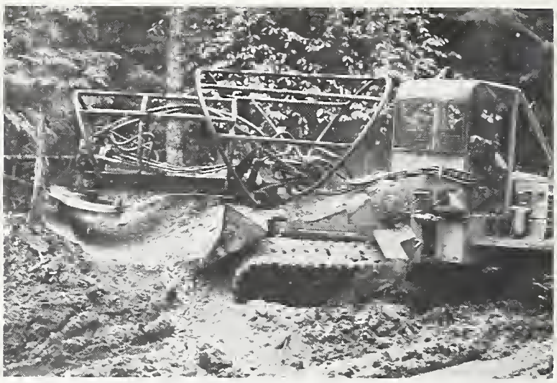


Figure 21. Trakmac/Trailmaker reducing in-ground stump.

The Trakmac/Trailmaker might be acceptable as a simultaneous strip or patch thinning and slash treatment device. But it is too slow for large logging slash, and offers no answer to the road construction slash stump problem or to the problem of treating partially buried residue.

Roanoke Robot and RMC Brush Cutter

The final two vertical shaft cutters are essentially rotary blades (primarily designed to mow down brush) that are on extension booms for mounting on prime movers such as motor graders, dozers, switching engines, or large truck beds. One is the Roanoke Robot Mountain Model (20), which we evaluated in 1966 as a brush cutter; the other is the Railway Maintenance Corp. (RMC) Brush Cutter. We tested a 5-ft diameter RMC cutting wheel, having two 21.5-in long blades, in our slash test facility.

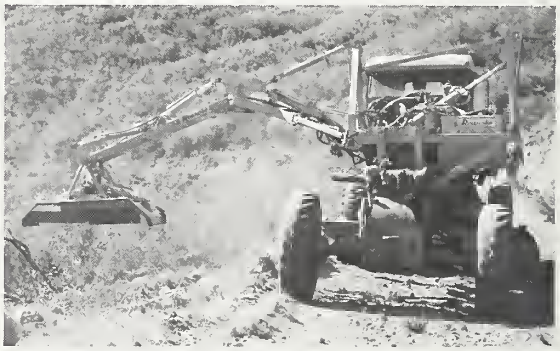


Figure 22. Roanoke Robot.

The Roanoke Robot (fig. 22) has a cutting head mounted at the end of a hydraulically controlled articulated boom, which is attached to a main mounting frame. The boom has a reach of 12.5 ft. The cutting head contains the cutter blade-arm section containing free-swinging, double-edged, 18-in long blades. They cut a 5-ft swath; the blade assembly is reversible. The machine proved capable of working in heavy brush with stems up to 4-in in diameter. It can easily cut 6-in green aspen, but is not efficient in chopping the stems into small pieces that can be scattered.

The RMC Brush Cutter has a 7-ft diameter Bush Hog Head having two 30-in swivel-mounted blades. The head is mounted on a telescoping boom and is driven at 1,050 rpm by a direct-coupled hydraulic motor that is protected by a relief valve in case a blade contacts an immovable object. Two booms can extend 25 ft out from each side of a small railroad switching engine, or a single 25-ft boom can be mounted on a 12-ton flat-bed truck. There is also a 15-ft boom for mounting the Bush Hog Head on a bulldozer. The Brush Cutter, it is claimed, has cut trees up to 14-in in diameter and cuts 6-in trees in 6 seconds.

Both rotary devices appear to have limited slash disposal use. They probably would do a credible job on piled or windrowed roadside slash if mounted on a proper carrier, and they may have potential in treating TSI slash, also if suitably mounted.

Transportable Timber Processors

This category of slash reduction equipment, as well as the four categories that follow (the various chippers and hammer machines), all share a major common problem: ineffectiveness of their cutting knives in slash mixed with dirt and rocks. We have observed three timber processors:

- Metro Chiparvestor Super Beever, Morbark Industries Inc., Winn, Mich.
- Tree Harvester, Precision Chipper Corp., Birmingham, Ala.
- Logger Model Utilizer, Nicholson Manufacturing Co., Seattle, Wash.

Morbark Chiparvestor

The Morbark Metro Chiparvestor Super Beever is a large, semi-trailer-mounted, transportable chipper originally designed to chip large trees that had to be removed along city streets, such as the many elms that died of Dutch elm disease. More recently, it has been proposed for on-site production of pulping chips (fig. 23). It is capable of chipping the entire tree, including tops and limbs, but it does not bark the trees it chips.

Figure 23. Morbark Chiparvestor.

The Morbark Chiparvestor uses a 75-in chipping disc, with three cutting knives, operating at 500 rpm. The machine is powered by a 310-hp diesel engine and uses a 20-ft-long loader boom. A conveyor belt system feeds the chipper. The overall dimensions of the machine are: length, 42 ft; width, 8 ft; height, 12.5 ft.

The machine handles a straight 22-in diameter stem, and chip size can be adjusted from 1/2 to 1 in. The machine produces 200 tons per day. For pulp chip production, the Chiparvestor would normally be used with tree felling and moving equipment, skidders, yarders, etc. The Chiparvestor retails for $90,000.

Figure 24. Area conventionally logged using chain saws and skidders with chokers.

The Morbark Chiparvestor was demonstrated on the Teton National Forest, Wyo., in 1971, to show that "clean logging" (no slash) is possible when all residues are chipped by the Chiparvestor. Four 20-acre sites were selected. Two were logged conventionally. The trees were felled using chain saws, and skidders with chokers brought the logs to the landing for loading onto logging trucks. Residues from this effort were left on the forest floor (fig. 24).

At the other two sites, "clean logging" was demonstrated. A Drott feller-buncher with a 24-in capacity felled and bunched the trees into two categories: those with saw-log potential and those to be chipped. The feller-buncher snipped trees close to the ground so no stumps remained, and everything was taken to the landing. Although a variety of skidding equipment was used, the best available equipment combination proved to be two Timberjack model 2301 skidders with grapples and one International Harvestor TD158 tractor working at the log landing. The whole trees skidded to the Chiparvestor were partially limbed and bucked as necessary for machine feeding. The Chiparvestor crew consisted of one man on the grapple and two swampers with chain saws on the ground. The effect of this effort was aesthetically pleasing, as no residue remained at the logging site (fig. 25).

The "clean logging show" resulted in a unit needing no further slash treatment, a pile of logs ready to be taken to a saw mill, and a mountain of "total chips." "Total chips" is Morbark's term for wood chips that are mixed with bark.

The success of clean logging depends in part on what effect the chips have on the forest floor. Conservationists who have seen the demonstration

Figure 25. Area "clean logged" using feller-buncher, skidders with grapples, and transportable timber processor.

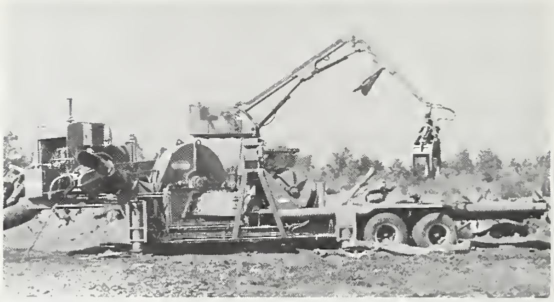


Figure 26. Precision Tree Harvestor.

area reportedly are pleased, but the judgment of silviculturists, biologists, and fire and recreation officials is needed.

The crux of the matter is, of course, economics. The market for total chips is fluctuating, although a big demand for them exists on the West Coast. If total chips can be sold, and if the removal of all organic tree material from the forest during harvesting proves feasible silviculturally, then we believe this clean logging concept will find widespread acceptance. The manufacturer estimates operating costs for the total system at about $800 per acre for typical log-producing areas.

If economical utilization of total chips becomes feasible, then the clean logging concept of this machine and the one described next present an attractive alternative to conventional logging practices. This equipment probably would not find use in road construction or TSI slash projects since processors cannot efficiently reduce such existing slash.

Precision Tree Harvester

The Tree Harvester (fig. 26) is similar to the Chiparvestor and was designed to do the same job as the Chiparvestor at a lower capital cost. The machine can chip 200 tons per day. It will handle a 22-in diameter straight stem, and chip size can be adjusted from 1/2 to 1 in. The chipping head is a 75-in diameter disc. Like the Chiparvestor, the Tree Harvester normally uses a truck or tractor as the prime mover, and also uses a grapple for loading material on the feed bed.

The feed mechanism consists of a hydraulically controllable, horizontal feed roller and two stationary vertical feed rollers (fig. 27). Even

Figure 27. Tree Harvestor chipper feed works.

irregularly shaped small-diameter stems can be fed easily, in part because hydraulic down-pressure can be applied to the horizontal feed roll. The Tree Harvester observed was powered by a single 350-hp diesel engine. The price is $86,000 f.o.b., Birmingham, Ala. When chipping oak logs and limbs, the machine produced a good commercial chip; however, a small percentage was considerably oversize. Like the Chiparvestor, this machine produces a "total chip" and is limited to the same capabilities as those of the Chiparvestor.

The latest, untested, version of the Tree Harvester uses two engines: a 130-hp diesel engine for the 1,800-psi hydraulic system, and a 310-hp diesel engine to drive the chipper disc. The theoretical capacity of this machine is 500 tons per 8-hour day, based on continuous feed.

Nicholson Utilizers

Logger Model Utilizers are similar in concept to the Chiparvestor and Tree Harvester machines, but are larger and more complicated because they bark straight-stem material before chipping. Two models are available. One model uses an 18-in capacity V-drum, 6-knife chipper; a second uses a 24-in capacity chipper of similar design. An operator-controlled hydraulic heel boom mounted on the machine loads the feed mechanism that moves material to the barker and chipping drum. Both models use automatic ring barkers with tandem holddown rolls. An 18-in bark conveyor discharges removed bark. The bark and branches, which makeup about 30 percent of the tree, are not chipped in normal operation but are mulched in a "hog" and blown out away from the unit.

A 350-hp diesel engine powers the 18-in chipper model, using a torque converter to drive the chipper and log feed. The 24-in model uses two 350-hp engines. Both models are equipped with generators, driven by a separate 250-hp diesel engine, to provide auxiliary power. The dual trailers for the two are approximately 8-ft wide, 40-ft long, and 13-ft high. The 18-in model weighs about 85,000 lb; the 24-in model, approximately 95,000 lb. A Utilizer costs approximately $185,000.

The Utilizer was demonstrated with support equipment similar to that used for the Chiparvestor and it also showed potential for producing about 200 tons of chips per day. Since the Utilizer barks stems before chipping, it produces clean chips. They were of uniform length and were discharged into a loading bin. Nicholson also recently placed a Complete Tree Utilizer on the market; this is a 22-in Utilizer model without a barker.

The Logger Model Utilizers might find application in a logging operation similar to the "clean logging show." However, tops and limbs would not be chipped. The Utilizers can take only tree stems, and still produce a clean chip, so slash problems similar to those encountered in normal logging would remain. Therefore, it is unlikely that the Logger Model Utilizers present any solution to Forest Service slash problems.

Small Mobile Chippers

Numerous small, hand-fed mobile chippers are available from firms such as Wayne, Fitchburg, Olathe, MB, Pitman, and others. These are regularly procured by the Forest Service under regional specifications. Although useful in some minimal roadside cleanup projects and in helping to clean areas at campgrounds and ranger station sites, they are too small to chip slash material of the size and type found after most logging operations, road construction work, and TSI activities.

Transportable V-drum Chippers

We have investigated three V-drum chippers. All are produced expressly for chipping slash, but are designed around a chipping head that is intended as a tool for chipping barkless mill residue and barked pulpwood; all three are one-of-a-kind prototypes:

Figure 28. Burkett Tree Hogger.

- Tree Hogger, C. V. Organic Fertilizers Co., Thermal, Calif.; Mr. R. Jack Burkett, President
- Mobile Chipper, Alpine Construction Co. (ACC), Bellevue, Wash.
- Wood Hog, Briere's Bulldozing Co., Seattle, Wash.; Mr. Fran Briere, owner.

All these units use a 60-in diameter, 36-knife chipping head manufactured by Black-Clawson Inc., Everett, Wash. These knives are 8-7/8 x 6-1/2 in. The assembled chipper head and rotor unit weighs 14,000 lb, costs about $16,000, and is designed for use with an engine up to 600 hp. The maximum rotor speed is 600 rpm; the spout opening is 32 x 30 in, allowing logs up to 25-in diameter to be chipped.

Burkett Tree Hogger

In the Tree Hogger (fig. 28), the Black-Clawson chipping head mounts on an alfalfa baler frame that serves as the prime mover. The machine weighs 14 tons, is powered by a 250-hp diesel engine, and uses a unique serrated drum feed system to assist a man in hand feeding.

This machine was tested on the Sierra National Forest, Calif. It required two swampers to initially feed a tree or other material into the feed mechanism. In many cases, the winch mounted on the front of the Tree Hogger was used to raise trees to the level of the feed mechanism. Designed for citrus orchard work, this machine did chip the slash fed into it; however, the effectiveness of the feedworks in handling slash material was poor. The production capacity has been measured at 1-1/4 tons per hour, with a per-ton cost of about $16.50.

The forest mobility of the Tree Hogger was unacceptable because of the wheeled vehicle on which it is mounted, and so it does not appear usable for forest slash needs.

Alpine Mobile Chipper

The ACC Mobile Chipper (fig. 29) has two 250-hp diesels to power the Black-Clawson chipping head mounted on a surplus U. S. Army tank. The tank has a grapple hook attached atop the rear portion. The Mobile Chipper is fed by a 15-ft long conveyor belt with the grapple as the loading mechanism. Associated equipment normally is required to move material into the grapple's range. It can handle straight logs up to 24-in diameter. A dual-blower exhaust system scatters the chipped material fairly evenly. The Mobile Chipper proved impossible to keep under power continuously because of feeding difficulties.

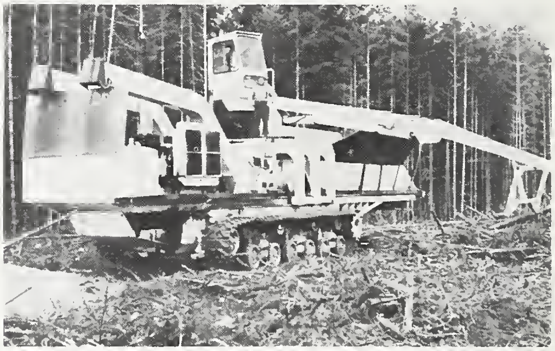


Figure 29. Alpine Mobile Chipper.

Briere Wood Hog

The Briere Wood Hog, a skid-mounted version of the Black-Clawson chipping head, was developed to dispose of road construction slash. The chipper is powered by a 240-hp diesel engine and weighs about 17 tons. Chips are carried from the Wood Hog to a truck by a conveyor system (fig. 30). The conveyor and Briere Splitter, a companion piece of equipment (described later in this report) that sections larger stumps prior to feeding them to the chipper, are powered by a hydraulic pump mounted on the front of the engine.

To overcome the problem of processing slash mixed with dirt and rocks, the owner of the Wood Hog is now using soft steel blades in the chipper; however, he is experimenting with blades and is fabricating a set from armor steel. He states that the blades can be "touched up" in place with a disk grinder by removing the top of the chipper.

Figure 30. Briere Wood Hog.

This takes about 20 minutes and is normally done once a day. Blades are bolted in place. Reground blades are installed once a week; this takes a "couple of hours." The operator generally tries to exclude rocks from the chipper but states that nails and wire present no problem.

The Wood Hog chips are coarser than those normally produced by large chippers so are more satisfactory for leaving on the ground. Problems of mobility, feeding, and sensitivity to rocks would seem to limit the Wood Hog's usefulness to chipping logging slash that has been accumulated at a landing. Even here it might not prove cost effective as, like all in-the-woods chipping plants, it is expensive to operate.

Other Drum-type Chippers

We have observed four other drum-type chippers proposed as possible solutions to slash problems:

- Ecolo Chipper, Nicholson Manufacturing Co., Seattle, Wash.
- 671 Log Chipper, Vermeer Manufacturing Co., Pella, Iowa
- Ecological Demolisher, Roy Industries Inc., Woodland Hills, Calif.
- Drum Chipper, Arasmith Manufacturing Company, Rome, Ga.

Nicholson Ecolo Chipper

Nicholson offers the Ecolo Chipper in five models, E-1 through E-5, with spout sizes ranging from 27 x 30 in through 96 x 40 in. The E-1 model weighs 13,000 lb; the E-5, 38,000 lb. We are aware of only three machines in use. It is claimed that they can reduce all forms of logging residue to chips, including brush and tree tops, logs, and stumps. They are available for diesel-powered portable operation and can be mounted on self-propelled track or rubber-tired vehicles and on highway trailers, truck beds, or barges. Nicholson can outfit them with the same hydraulic loader for lifting material from the ground to the infeed chain bed that is available on its Utilizers. Capacities of the models vary from 40 to 225 tons per hour. The large 48-in diameter chipper drum (500 rpm, maximum) has up to 28 specially hardened steel knives that are bolted into individual pockets and can easily be changed by one person.

In mid-1971, we saw a prototype Ecolo Chipper (fig. 31), expressly designed to chip building debris and railroad ties, as well as slash mixed with dirt and rocks. The machine had an exceptionally large feed opening (15 in wide x 40 in high) relative to the size of the unit, and was constructed to withstand the punishment of tough foreign material that might be mixed in with the wood to be chipped. Further, the anvil in the device is supported by a shear pin so that when a rock or other impenetrable object is encountered, the anvil drops away like a trap door, and tough matter is ejected without seriously damaging the chipping blades.

The prototype machine chipped brush and tops, large logs, solid railroad ties with spikes still embedded, and building rubble, including several large pieces of brick, concrete, and rock. Little damage to chipping blades occurred.

Figure 31. Nicholson Ecolo Chipper.

The Ecolo Chipper handled large solid materials without needing excessive horsepower because it has a variable speed (31 to 62 fpm) feed arrangement, allowing a fast production rate on bulky, less solid materials (such as brush or top and limbs) and yet providing slow reduction of heavy material (such as stumps). In addition, since the variable speed feed is synchronized to drum rpm, chips of fairly uniform size resulted especially considering the diverse nature of the material fed to the machine. Because of the chipper's blunt blade, the reduced residue is nearly cubic, unlike that produced by chippers designed for commercial paper-making chips. Several who witnessed the demonstration felt that the wood cubes would make acceptable "hog" fuel for boilers and kilns.

The Ecolo Chipper shows promise for all classes of slash.

Vermeer 671 Log Chipper

The Vermeer 671 Log Chipper (fig. 32) is a large trailer-mounted, drum-type chipper, powered by a 125 hp diesel engine. Each of the 45 one-in square cutters on the 4 ft long chipper rotor has a carbide tip and, according to the manufacturer, is not sensitive to damage by dirt and rocks. The 671 Log Chipper weighs 15,140 lb and is 14.5 ft long, 7.5 ft wide, and 11 ft high. The manufacturer's retail price is $26,000.

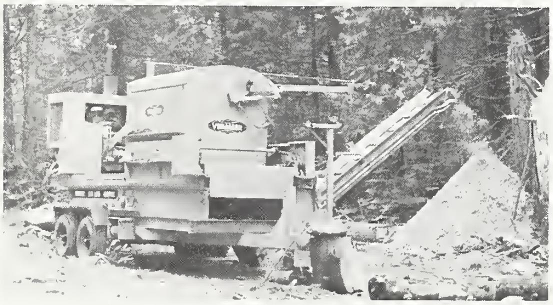


Figure 32. Vermeer 671 Log Chipper.

The 671 differs from other chippers in that the feed mechanism is a log bin that hydraulically traverses the 8 in diameter drum 15 times per minute, much in the manner of a wood planer. The bin opening accepts logs of approximately 4 ft diameter and up to 6 ft in length. To load, the bin's movement across the drum is stopped, and its lid is raised hydraulically. After loading, the lid is closed, and the bin is activated again.

The 671 was tested in mid-1971 on the Sierra National Forest, Calif. (10). Logs, stumps, and brush were loaded into the 4 x 4 x 6-ft bin. Of the trees (80 percent ponderosa pine and 20 percent jeffrey pine, incense cedar, and some fir and oak) skidded to the chipper, 90 percent or more would not fit into the bin and had to be cut by a chain saw into lengths less than 6 ft. Logs larger than 30 in in diameter were not effectively chipped. The machine discharged 1/2 x 1/2 x 1/8-in chips onto a conveyor. Later, a tractor scattered the chips that had accumulated. During the test the 671 emptied a full bin in about 7 minutes, whether chipping heavy logs or light branches.

When chipping logging slash, the 671 averaged only about 7 tons per hour. Testing also revealed other deficiencies: comparative high cost; too fine a chip resulting in a volume 1.5 times the volume of the unchipped logs, and these chips were concentrated in a pile; excessive noise; and a separate device was needed to feed the unit. During the demonstration the bin was loaded with a small front-end loader, which could not do an effective job.

Even as a TSI slash treatment tool, the 671 has some serious limitations. Although it can easily handle most TSI slash, the material must be cut into lengths less than 6 ft. In a tractor-thinning operation it is possible that once the slash is pushed down it could be brought to the machine with a tractor using a brush rake, sawed into suitable lengths with a chain saw, and placed in the machine with a loader. This operation, which probably could treat 5 tons of slash per hour, would cost about $10 per ton. The chipper would have to be relocated often; however, the tractor with a brush rake could do this. Slope limitation would probably be about 20 percent, and the tractor would have to push the concentrated piles of chips into an acceptable configuration on the forest floor.

Since the 671 Log Chipper cannot process large amounts of slash quickly, it is not recommended for general use on heavily wooded forests and roads. It may play a role in small areas such as campgrounds, however, where total cleanup of brush, root wads, and small logs (less than 3 ft-10 in diameter) is desired, particularly where chips can be trucked away. For heavier slash concentrations of this kind, the Vermeer 1081 Log Chipper could be considered. The 1081 was not marketed at the time of our test. It weighs 44,680 lb, has two cutter rollers, a 10 x 5-ft traversing bin, and a built-in loader grapple.

Roy Ecological Demolisher

This machine was originally designed to pulverize debris cleared for housing developments, allowing the debris to be disposed of on-site, rather than hauled to a landfill. It handles orchard residue and even large eucalyptus. We saw a eucalyptus stump of about 5-ft diameter chewed up in just over 3 minutes.

Figure 33. Roy Ecological Demolisher.

The Ecological Demolisher (fig. 33) is a trailer-mounted, multiple-drum, wood-waste shredding machine. The mechanism is housed in a 25 x 8-ft bin that contains six bottom-mounted shredding drums similar to the 671 Log Chipper drums. The entire machine weighs 71 tons, stands 12-ft high, and is 82-ft long (when towed by a large truck-tractor). A 1,050-hp diesel engine supplies power. Each shredding drum is 12-in in diameter, 25-ft long, and is powered by its own hydraulic motor that individually controls rotation speed (up to 2,000 rpm) and direction. Welded to the outer surfaces are 2,500 wedge and cam-shaped carbon-steel teeth that shred and tear, reducing wood to a residue fine enough to pass between a grill screen to a conveyor belt and out to a chip pile.

The machine processes about 200 tons per hour. The residue is a bit coarser than what the Nicholson Ecolo Chipper produces and resembles a torn particle, rather than a knife-cut papermaking chip. Only about three prototype Demolishers have been built. A production machine for forest road slash disposal will cost an estimated $300,000.

The Ecological Demolisher was demonstrated while reducing construction material residue from buildings in the Los Angeles area, in addition to the eucalyptus logs and stumps. The machine is top-fed by associated loaders or by crane. The residue is then fed out by the conveyor belt for disposal. Because of the nature of the shredding drums, it should be quite insensitive to rocks and dirt. This agrees with reports of the owner, who is using the machine to breakup building construction waste at a sanitary landfill.

It is not known when, or even if, a model will be designed specifically for slash disposal but the manufacturer appears to have the engineering know-how and financial resources to accomplish this if potential sales are shown to exist. Because of its size and inherent mobility problems, the Ecological Demolisher probably will never find use on TSI slash, but at landings or on prepared roadbeds it could dispose of any slash generated by logging or road building operations.

Arasmith Drum Chipper

The Arasmith Drum Chipper (fig. 34) has drums either 42- or 50-in in diameter with lengths up to 10 ft. Bolted to the drum, in a spiral pattern

Figure 34. Arasmith Chipper.

Figure 35. Chipper drum with knives.

around the drum surface, are cutting knives (fig. 35). The drum rotates at about 270 rpm, and can chip hardwood or softwood logs while essentially separating bark from the wood chips. The Arasmith can chip logs up to 60-in in diameter when they are bucked to chipper drum length, making an acceptable chip for pulp use.

It is difficult to overload the device because, by design, the feed is limited to about 1/4-in per revolution. Thus, installed horsepower can be reduced in this type of chipper to that which mobile equipment could reasonably provide. The chipper will tolerate small rocks (dime size) and large rocks (20 lb) will not cause permanent damage. It has a high production rate—on large models more than 50 tons per hour.

In late 1973 we visited Cross City, Fla., to observe the operation of an Arasmith Chipper 50-in in diameter and 5-ft long, with 86 knives, driven by a 300-hp electric motor. The drum itself was mounted in a split-type bearing that allowed bearing changes without removing the drum. The drum wears at each knife point and, after about 6 months of operation, it is necessary to buildup the drum. This operation is reported to take about 6 hours. Also, two sets of knives (alternated between almost daily sharpenings) last about 6 months; knife changing takes 45 minutes.

It has been reported that a 100,000-lb load of chips has been produced and delivered to a rail car in 1 hour. The complete plant was estimated to cost about $50,000, including $19,000 for the chipper. The Arasmith design offers much potential for utilizing logging and road construction slash because it is not too sensitive to rocks and dirt, has a relatively high production rate, and it barks the material.

Flails and Hammermills

Flails and hammermills use blunt hammers or flails that break and crush, rather than cut or chip, material fed into them. Flails do not work the material against an anvil, whereas hammermills do. Although no power consumption figures are available for flails and hammermills vs. chippers, the former require more power to operate. Exact data on power needs are being sought at the Center's slash cutting test facility.

Miscellaneous Hammermills

We are aware of five hammermills that reduce waste wood at mills. Although these machines should not be sensitive to rock damage, as now designed, they are probably too heavy and expensive, and otherwise ill-suited, for slash reduction. To our knowledge none have been incorporated into a slash disposal system. These five have similar hammers without bladed surfaces:

- No-Nife Hog model 350, Williams Patent Crusher and Pulverizer Co., St. Louis, Mo.
- Apache model 5, Apache Hammer Hogs, Seattle, Wash.
- Salem model SR30, Salem Equipment, Inc., Salem, Oreg.
- Schutte model 1380, Schutte Pulverizer Co., Inc., Buffalo, N.Y.
- Montgomery BLO-HOG, Jacksonville Blow Pipe Co., Jacksonville, Fla.

Two machines have been proposed for slash work:

- Tree Eater, Tree Eater Corp., Gurdon, Ark.
- Alley-Gator, Alley-Gator Manufacturing Co., Portland, Oreg.

Tree Eater

The Tree Eater is no longer available on the market, but it has been used for slash treatment over the years. Essentially it is a front-end hammermill powered by a 318-hp diesel engine mounted on a Case 750 tractor with torque converter drive (fig. 36). Overall dimensions are 17.5-ft long, 10.5-ft high, 8-ft wide. The engine drives the flail drum through a plate clutch and two sets of V-belt bands. The drum, which rotates at 1,800 rpm, is about 30-in in diameter and 6-ft in length and has four rows of cutting arms. The 14-lb free-swinging hammers, 72 in all, are mounted on four full-length hinge pins. The machine, weighing about 25,000 lb, cost approximately $40,000 with a spare set of cutting arm assemblies.

Figure 36. Tree Eater.

During slash treating operations, the height of the flail cutters above ground level can be varied up to 8 in by skids at the bottom of each side of the drum-bearing support frame. For traveling or special cutting, height can be controlled hydraulically over a range of 0 to 27 in above ground. To help push trees forward as they are cut, a hydraulically operated push bar is above the cutter drum.

We have seen this machine in field use for a period of years, both in reducing small logging slash and for simultaneous thinning and slash treatment. It was demonstrated on the Tonto National Forest, Ariz. (18), in 1964, again in 1966-67, and also on the Deschutes National Forest, Oreg. in 1971.

The Tree Eater's hammers impact slash material as the machine passes over it (fig. 37). Best results are obtained when the wood is struck at right angles to the grain. In the Arizona tests the Tree Eater seemed equally effective on both dead and green wood. The softer green wood (pines, pine slash, and most shrubs) produced long, fine shreds of material, while the harder wood (oaks, manzanita, and dry slash) was reduced to chips and splinters.

Figure 37. Cutting drum with flail cutters.

Because of the need in some areas to run with the cutter set at 4-in or higher to minimize bit wear and avoid rocks, some of the smaller stems were not completely chipped once they were felled. For large logs, only the exposed upper surface was removed and chipped.

During a demonstration test and while in use over a 12-month period on the Tonto National Forest, the Tree Eater demonstrated its ability to fell trees and masticate all but the main stems (10-in in diameter and over) of the larger, tougher species. Brush, including chapparal, and trees up to 6-in stump diameter were almost completely shredded and reduced to a mulch consistency.

Figure 38. Treated ponderosa pine slash—one pass of Tree Eater (hat sits on untreated segment.)

In the Oregon tests on hand-thinned ponderosa pine slash, the machine did an acceptable job of reduction for about $50 an acre (fig. 38).

The Tree Eater generates dust storms in almost all soils. We installed a cab and cab pressurizer to filter the air to protect the operator from the dirt and dust. Nevertheless, visibility is limited and a swamper must proceed the machine to act as a seeing-eye guide. Even so, the operator cannot see what the machine is doing as he operates the controls. The noise level is high, averaging 97 dBA at 50 ft from the machine and 100 dBA at the operator's ear.

The tractor on which the Tree Eater is mounted is too small and underpowered for efficient operation. Terrain and soil, rather than ground cover, are the limiting factors facing the machine. Rocks, highly abrasive soil, or both cause costly downtime. Working in decomposed granite under dry,

dusty conditions, the machine averages 5 hours of operation per 8-hour day. Even when treating coniferous brush in gently rolling topography (slopes under 20 percent) with a small amount of surface rock and a pumice soil texture, there was good treatment, but frequent breakage and high maintenance costs.

Brakes, slope ability, hammer-blade life, and mechanical reliability of auxiliary engine clutch and drive belts were all submarginal. The cutting flail assemblies cost about $500 to service and require a day to change. The machine's poor maneuvering ability resulted in damage to a good many residual trees when performing TSI work. All-in-all, the Tree Eater did a good job of intensive cleanup, but many serious problems have to be overcome before it can find acceptance as a Forest Service slash treatment machine.

Alley-Gator

The Alley-Gator is a large hammermill wood-reduction device mounted on a 25-ft trailer (fig. 39). It has a height of 10 ft and width of 8 ft. Its many conveyors are mostly powered by hydraulic motors. The machine itself is powered by a 6-cylinder 200-hp turbocharged diesel. The main cutting head is a drum-type hammermill similar to the Tree Eater's. The feed opening, though 6 ft long, is only about 6 in wide.

We observed the Alley-Gator successfully dispose of old wooden pallets and other construction wood scraps and produce a satisfactory chip. The feed mechanism (fig. 40) breaks the pallets as they are fed to the hammermill. The unit, however, appears unsuitable for Forest Service slash needs as its size would limit it to on-road use, and the feed opening is too small.

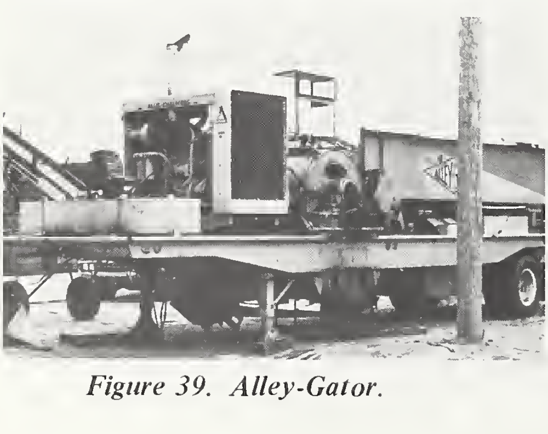


Figure 39. Alley-Gator.

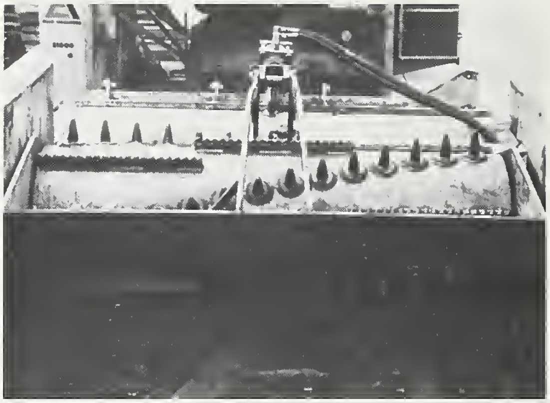


Figure 40. Alley-Gator feed works.

Disc-type Stump Chippers

The following disc chippers are somewhat effective in reducing stumps while the stumps are still in the ground:

- Stump Master, Arps Corp., New Holstein, Wis.
- Stump King, Wayne Manufacturing, Co., Pomona, Calif.
- Trakmac/Trailmaker (see under previous discussion of Vertical Shaft Cutters).

Each of these machines essentially has unshrouded circular cutting heads with replaceable carbide teeth on the periphery of the discs. As the chipping discs rotate at high speed and contact the stump, the stump is chipped away to ground level, or even below.

Arps Stump Master

The Stump Master model ASM-1 is hydraulically operated and is designed for mounting on three-point hitch tractors of 40 hp or more. It weighs 1,320 lb, has a PTO speed of 540 rpm, and its single 36-in diameter cutting wheel contains 21 carbide-tipped teeth. It is claimed this device can cut 37-in-high stumps down to 16-in below ground level.

Wayne Stump King

The Stump King model SK65 has dual 18-in cutting wheels on a slim, articulating, hydraulically

controlled arm. This provides a 64-in forward reach, a 4-ft high vertical reach, a 27-in cutting depth, and a range of lateral movement over 12 ft. The device operates with a 65-hp engine and has a water-spray system to control chip dust and cool the cutting head.

Stump Splitters and Removers

Machines and devices in this final category are used to split stumps, then remove them, as well as to breakup larger cull logs and root wads. This type of slash is common in forest road construction. It is necessary to split these larger pieces of waste wood so they can be put into chippers for further reduction or loaded onto trucks for export from the forest site. Also root wads have to be broken up to remove entrapped rocks and dirt before further processing so blades or hammermills can safely handle the material or to insure effective burning.

Numerous tractor attachments are marketed for pushing or pulling stumps out of the ground, for cutting lateral roots of the more stubborn stumps, and for splitting extra large stumps so they can be taken out of the ground in manageable pieces. A complete review of these rake, blade, plow, and splitter tools can be found in a previous Center report (17). Only the most applicable are described here.

A shearing blade mounted on a crawler tractor is one form of stump treatment device. The blade is equipped with a wedge-like projection called a stinger that is welded or bolted to the blade. The stinger is basically a protrusion that acts like a scythe being driven by the total horsepower of the tractor. Shearing blades, unlike bulldozer blades, have a flat sole at the bottom to allow them to float on top of the ground without digging in. At least two shearing blades are offered on the market:

- K/G Clearing Blade, Rome Plow Co., Cedartown, Ga.

- V-tree Cutter, Fleco Corp., Jacksonville, Fla.

They have been used effectively in hardwood stands where stump removal was not needed. They are not recommended for use in areas having more than a few isolated rocks.

Figure 41. Rome K/G Clearing Blade.

Rome K/G Clearing Blade

The Rome K/G is an angle blade, featuring a sharp cutting edge, a stinger, and a guide bar that allows the tool to cast the cut material to one side. It comes in sizes to fit D4- through D9-type tractors. The blade assemblies run from 2,280 to 5,540 lb and have an overall length (trunnion to stinger tip) of from 14 ft-9 in to 21 ft-4 in. Blade angle is 30° and the blade can be operated either by cable or hydraulically. The replaceable cutting edges and stinger are usually resharpened daily with a portable grinder. The sharp stinger (fig. 41) can split large trees (7-ft diameter) and then the angled cut-

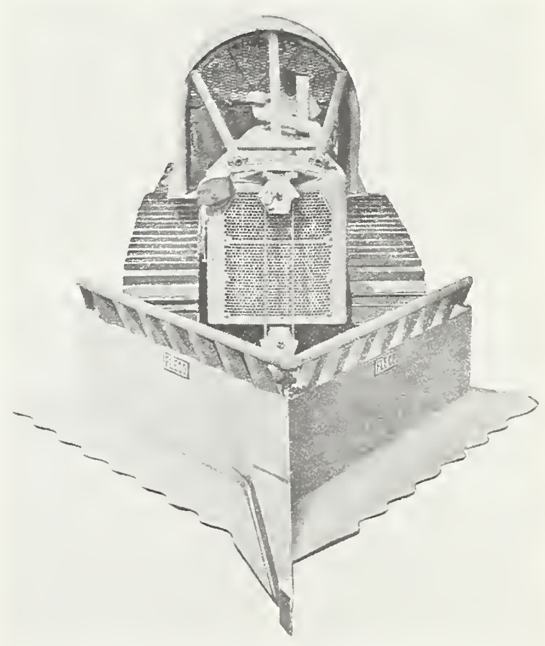


Figure 42. Fleco V-Tree Cutter.

ter shears stumps flush with the ground. By tilting the angled blade, the operator can grub out the severed stump from below ground level.

Fleco V-Tree Cutter

The cutting blade of the V-Tree Cutter has serrated cutting edges, a center-mounted stinger, and guide bars that cast material to both sides of the tractor. The V-blade mounts directly on the tractor's trunnions and is available for cable or hydraulic control on D4 through D8-type tractors (fig. 42). The "V" is in two sections that bolt together to form the working tool. It is designed for clearing down to ground level and cannot remove subsurface growth.

Tractor-mounted Stump Splitters

These tractor-mounted stump splitters are available:

- Stump Splitter, Young Corp., Seattle, , Wash.
- SM-4 Stumper, Rockland Inc., Winter Garden, Fla. .
- Detachable Stumper, Fleco Corp., Jacksonville, Fla.
- SSR Stump Splitter, Fleco Corp.

The Young Stump Splitter comes in two sizes (72- and 96-in long) and is essentially a heavy (1,050 and 1,330 lb) pointed tool of cast alloy steel with a front wedge ground to a sharp edge. The device has flares in two directions to aid the splitting action and permit easy withdrawal.

The Rockland SM-4 Stumper is a multitoothed attachment for applying the full force of a tractor to pop out a stump. It is available with an optional splitter to speed large stump removal. The device can be ordered in appropriate sizes for D6- through D9-type tractors.

The Fleco Detachable Stumper (fig. 43) is a similar one-piece cast tool for connecting to a crawler tractor's C-frame. It has a curved face to penetrate hard soil and cradle stumps for removal. For larger or tougher stumps, a detachable splitter is also available as an attachment that can be welded to the left side of the stumper. It concentrates the

Figure 43. Fleco Detachable Stumper.

power of the tractor on a single focal point for maximum splitting action.

The Fleco SSR Stump Splitter, a cast heat-treated alloy steel tooth for splitting and shattering stumps, rear mounts on a crawler tractor like a stinger on a hinge-type ripper bar. It comes in two sizes—–1,675 and 2,100 lb—–and is priced at about $1,000.

Bles Stump-Axe

A device called the Stump-Axe (fig. 44) is available from the Bles Stump-Axe Co., Inc., McLean, Va., for mounting on a conventional 3/4- or 1-yd crawler shovel or a 35-ton rubber-tired crane. Essentially, it is a pivoted arm, 11 ft long, hung from a 20 ft welded boom built up of two box girders. The lower half of the pivoted arm is a blade with a 5-ft curved cutting edge. The device weighs about 5 tons and works in a manner similar to the stumpers just described, except it applies force as a back hoe would and can slice stumps

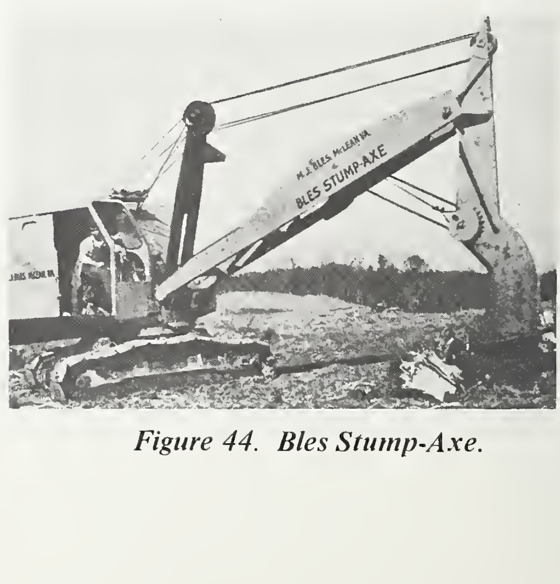


Figure 44. Bles Stump-Axe.

downward from the top or upward from the bottom. The manufacturer has run field tests and claims the Stump-Axe can easily remove stumps 3- to 6-ft thick. It is priced at about $10,000 for the axe and boom.

Wagner-Bartlett Stump Splitter-Remover

The Wagner Manufacturing Co., Portland, Oreg., markets the Wagner-Bartlett Stump Splitter-Remover, designed to remove large stumps up to 96-in in diameter and also to cut up root wads and cull logs. The Stump Splitter-Remover is available in four sizes:

- F-40, front mount, 40-in capacity, $16,500
- F-60, front mount, 60-in capacity, $18,750
- R-66, rear mount, 66-in capacity, $29,000
- R-96, rear mount, 96-in capacity, $45,000.

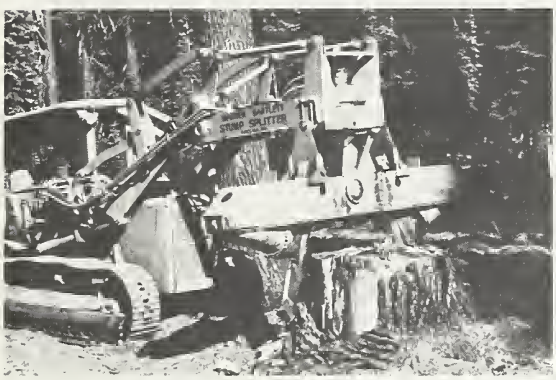


Figure 45. Wagner-Bartlett Stump Splitter-Remover.

The hydraulically powered device can be mounted on track-type or rubber-tired end loaders and consists of two large cylinders that drive the T-1 steel splitting blades through the heart of the stump with 247,000 lb of force. Figure 45 shows the F-60 splitting a 50-in stump. The forward sweep of the carriage is followed by a reverse sweep that flowers out and pushes the splits of the stump out of the ground. The carriage can rotate 85° either side of center so that only one approach by the prime mover is necessary for making as many splits

Figure 46. Stump splitting knives.

as required to finally remove the stump. Splitting a 60-in diameter stump into quarters takes 90 seconds. Figure 46 shows the knives on the R-96 model, with push-off cylinder extended. The machine's unique feature is its ability to cut up any cull log or stump in or out of the ground.

Pemco Cable Cruncher

Another splitter on the market is the Pemco Cable Cruncher from the Perpetual Environment Manufacturing Co. (Pemco), Missoula, Mont. Its purpose is to reduce slash from logging, TSI, and especially road construction to manageable size by mechanical breaking. This 5,000-lb device is 10.5-ft high and was originally offered in 1970 by Ernest P. Cox, its inventor, as the T&C Slash Breaker. It is an attachment designed for use with double-drum, cable-operated cranes (fig. 47).

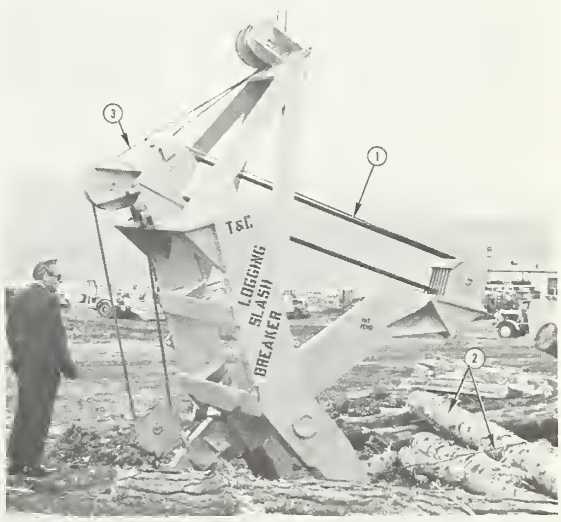


Figure 47. Pemco Cable Cruncher.

The implement's three jaws are placed over the cull log or other slash to be broken by an opening cable (No. 3 in fig. 47) and two small positioning cables (No. 2). The closing cable (No. 1) drum is then activated, and the jaws crush the slash material. The maximum jaw opening is 40 in, with a distance between the outside teeth of 4 ft. The jaws can be used either for breaking logs or for grappling them, but the cable threading at the jaws must be altered to do one or the other; the change-over, accomplished with a simple wedge, takes 30 seconds.

A prototype of this machine was demonstrated in 1972. It effectively broke green 24-in white fir logs, and could easily handle three or four 12-in to 15-in logs simultaneously. In one case, a green 30-in white fir log was split along its longitudinal axis by engaging the teeth on its diameter and lifting with the closing line. Each half was then easily broken in the normal manner. Positioning and breaking times vary greatly, but averaged about 15 to 20 seconds. This device appears to have applicability in reducing cull logs up to 30-in in diameter. However, it could only be used where breaking and scattering is an acceptable treatment, or to prepare material for burning.

Scale models of other designs for this device have been displayed, including two hydraulic models—one for a hydraulic crane and one for front mounting on a D6-type crawler tractor.

Hydraulic Splitters

We have looked into three hydraulic splitters that are essentially designed for splitting logs:

- Hydraulic Log Splitter, Carthage Machine Co., Inc., Carthage, N.Y.
- Woodsplitter model 1000, Bles Stump-Axe Co., Inc., McLean, Va.
- Splitter, Briere's Bulldozing Co., Seattle, Wash.

The largest of these is the Log Splitter, powered by a 10-in bore x 9-ft stroke hydraulic cylinder operating at 3,000 psi that provides 100 tons of thrust for splitting into six sections lengthwise logs up to 10-ft in length and 48-in in diameter, in less than a minute. The six-way axe is interchangeable with two splitting axes that are mounted at right angles to each other for treating 2- to 3-ft diameter logs.

The Woodsplitter model 1000 can handle logs up to 5.5-ft in length and has a T-1 steel cutting blade sharpened on both edges so that it cuts on the out stroke, then the log is flipped for cutting on the return stroke. The out-stroke ram force is 36,300 lb, the return force, 30,250 lb. The blade is 26-in high and is 8-in wide at the bottom, 6-3/4-in at the top. The device weighs about a ton and comes with a flat or skid mount, or a three-point hitch. Because of its extreme size, the machine would not appear to have much place in Forest Service slash work. Also, the cost of reducing slash with the model 1000 would be high.

The Briere Splitter is a skid-mounted, guillotine-type splitter offered for use in conjunction with the Wood Hog (see under Transportable V-drum Chippers), from which it receives its hydraulic power. When hooked to the Wood Hog's front-mounted pump, it adequately splits root wads up to 30-in in diameter.

SLASH BURNING

Slash that cannot be utilized or that is best not left on the ground should be burned. However, problems caused by slash burning are many. When slash is dry enough to burn, burning is usually unsafe because of the high potential fire danger. On the other hand, if weather conditions permit safe slash burning, the material probably will not burn well. Then there is the smoke and air pollution. To overcome such problems, slash must be burned at 1,600°F or over, and this cannot be attained without special equipment.

Broadcast Burning

For logging slash, the almost universally accepted slash disposal method, at least in the western United States, is broadcast burning. It is the concept of burning slash in place, without any preprocessing except, perhaps, compacting. A great deal of research exists to document the fact that broadcast burning creates air pollution problems and occasionally leads to massive wildfires (2, 6, 13). Thus, it is necessary to provide fire protection to prevent the broadcast burn from escaping and becoming a wildfire. Additionally, since burning must be carried out when fire danger is low, broadcast burning does not provide as complete reduction of the fuels as could be obtained during periods more favorable to good burning.

So this method leaves large residues resulting from partial or incomplete burning of larger slash pieces,

Figure 48. Fleco Rock Rake.

cull logs, and so forth. This is particularly displeasing to the public, as it gives the appearance of vast waste. Then too, partial burning of larger fuels kills the natural decay organisms, thus retarding eventual decomposition of the material. Access to a site can be impaired up to 50 years by this partially consumed wood.

Broadcast burning is not seen as a viable disposal method for road construction or TSI slash.

Pile Burning

In pile burning, accumulated slash material is concentrated into piles and burned. A tractor can be used to tend the fire by continually bunching the pile as the burn progresses, thereby intensifying the consumption of the material. The fire is easier to control since it is concentrated in one area, and a hotter burn is achieved. However, one major problem with pile burning is the entrainment of dirt and rocks in the pile. To overcome this problem, piles should be made with rakes rather than dozer blades. A Fleco Rock Rake (fig. 48), typical of many such commercially available tractor attachments, was used to make the slash pile shown in figure 49. Reduction here was exceptionally good.

Figure 49. Relatively successful pile burn.

Figure 50. Not too successful pile burn—poor reduction.

Most pile burns are not this complete, since it is difficult to attain temperatures high enough for complete combustion (fig. 50). "Burners" are available (fig. 51) that help promote combustion by supplying oxygen with a fan plus a measured amount of fuel oil sprayed through a pump. These units appear to improve combustion efficiency only marginally.

Pile burning, like broadcast burning, leaves unburned residues, can cause air pollution, and tends to create a fire hazard with live ash embers (fig. 52).

Burning Boxes

Several different configurations of metal boxes (16) have been used for burning slash. These are loaded by tractor loader, backhoe, or by hand. The intent is to confine the fire and promote cleaner burning. This method probably does reduce the danger of an escaped fire but certainly does not significantly increase combustion efficiency over that obtained by pile burning.

Figure 51. Fleco Brush Burner.

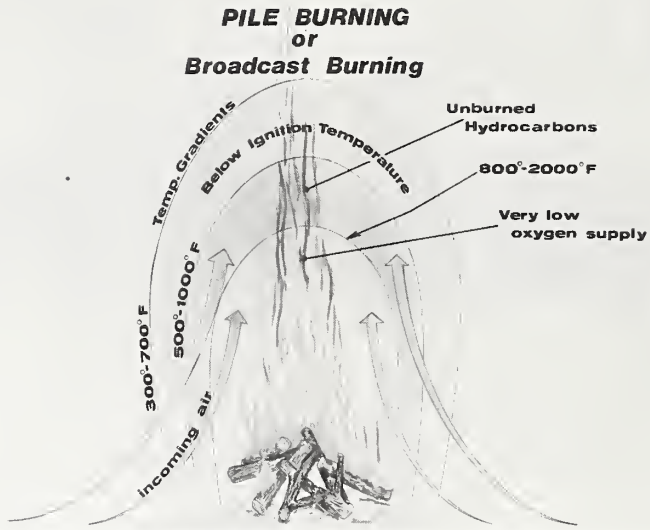


Figure 52. Temperature profile—incomplete combustion when pile or broadcast burning.

Air Curtain Burners

To produce clean (no smoke) burning, a temperature of at least 1,600° F must be reached. This can be accomplished with air curtain burners. We know of three that are available – two pit burners and a self-contained unit:

- Air Curtain Destructor (ACD), DriAll, Inc., Attica, Ind.
- Thermal Airblast Incinerator, Thermal Research and Engineering Corp., Conshohocken, Pa.
- Air Curtain Combustion Unit, The Camran Corp., Seattle, Wash.

Essentially, this treatment approach (fig. 53) consists of dumping unusable slash material either into earth pits or into large fireboxes and using forced air to achieve intense combustion and to drive volatile gases into an air curtain where secondary

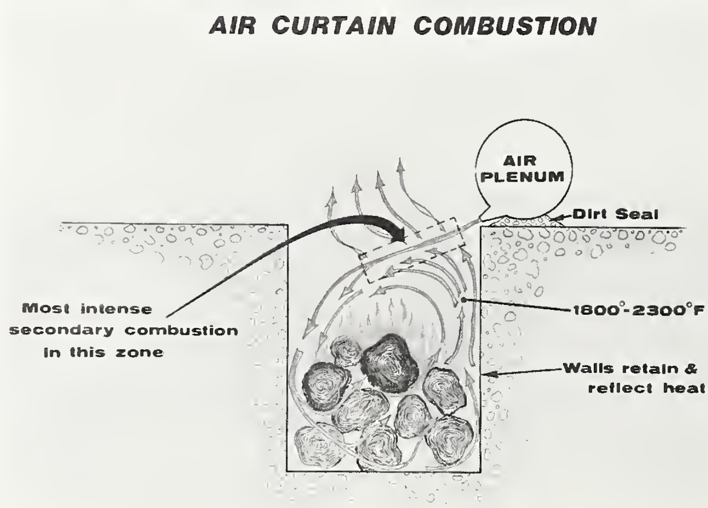


Figure 53. Principle of air curtain combustion.

Table 5. Air Curtain Destructor Specifications

FEATURES	TYPE OF UNIT			
	Stationary		Portable	
Model designation	ACD-10	ACD-21	ACD-21	ACD-42
Nozzle length (ft)	10	21	21	42
Nozzle air velocity (fpm)	10,000	10,000	10,000	10,000
Air flow (cfm)	8,000	17,000	17,000	34,000
Fan–axial flow, variable pitch, 12 blades per stage–				
Diameter (in)	34	34	34	45
No. of stages	1	2	2	2
Power required, continuous (hp)	15	30	30	60
Approximate capacity (tons/hr)	2-3½	4-7	4-7	8-14
Approximate price–not including motors or engines ($)	3,500	5,500	6,500	10,500

combustion takes place. This results in a complete, no-smoke burn that also destroys hydrocarbons that escape into the air in broadcast or pile burning.

Air curtain burning has proven to be one of the most effective methods of treating slash. When proper techniques are used, total treatment time is short and remaining residue is less compared to other burning techniques. The chance of starting a wildfire while using an air curtain burner is almost nil.

Air Curtain Destructor (ACD)

The DriAll ACD, essentially T-shaped duct work with a fan, motor, engine, etc., is available in four models—two stationary for permanent installation and two portable. Specifications for the four ACD models are presented in table 5. Air for the air curtain is generated by an aerodynamic axial-vane fan and is discharged along the top of the "T," which is a continuous truss-reinforced nozzle. This nozzle provides a positive streamline air flow of uniform velocity across and down into the entire length of the burning pit.

The burning pits for use with an ACD can be dug with a front-end loader or backhoe and should be 10, 21, or 42 ft in length (depending on the model ACD used). The recommended pit width is 8 ft, with a depth of 12 to 15 ft. Pit walls should be kept as close to vertical and parallel as possible. In some soils this is easy, in others difficulty in maintaining satisfactory walls has been encountered. After the pit is prepared, the ACD is set in place next to the pit with the nozzle parallel to, and 3-in to 6-in back from, the pit.

The two stationary models are skid-mounted for transportation to a permanent site and are usually used in conjunction with a heat-resistant concrete pit. The portable models come with their own rubber-tired running gear (ACD-21, 4 tires; ACD-42, 6 tires) and fold for towing to the site.

The slash material to be disposed of is placed into the pit and ignited with diesel fuel, "fuel boosters," or oxidizer pellets, if necessary. When in operation, the pit is continually fed new material. The ACD fan moves air through the

Table 6. Air Curtain Destructor Testing

Location	*Dates*	*Fuel* 1/	*Average moisture (%)*	*Typical size (ft)*		*Loading crane capacity (tons)*	*Maximum burn rate (tons/hr)*
				Diameter	*Length*		
Equipment Development Center, San Dimas, Calif.	Nov. 22-24, 1971	Eucalyptus (80%) Orange (15%) Palm & pine (5%)	20	3-5	30	12½	16.0
Zigzag Ranger District Mt. Hood National Forest, Oreg.	May 15-19, 1972	Douglas-fir (75%) Cedar (10%) Hemlock & other (15%)	55	3-5	35	60	7.5
Columbia Gorge District, Mt. Hood National Forest, Oreg.	May 22-31, 1972	Douglas-fir (85%) Hemlock & other (15%)	45	3-5	35	60	14.8
Nine Mile District, Lolo National Forest, Mont.	June 15-21, 1972	Larch and lodgepole	30	½-1½	10	12½	21.0

1/ Stumps and root wads were burned at all locations.

ducting. The air moves at a measured velocity of 10,000 fpm, or more than 100 mph across the burning pit and down into it. The hot gases (smoke) and any ashes and cinders are forced upward into the air curtain, and secondary combustion occurs, resulting in clean burning.

We tested a DriAll ACD-42 at four sites (see table 6). Test results were good at all locations. Based on 10-days burning on the Columbia Gorge District, the ACD-42 operated at $5.70 per ton of fuel, including costs of site preparation and cleanup, ACD admortization, support equipment, and personnel. This cost can be reduced even further on a large-scale operation with judicious selection of proper support equipment. For example, we estimate a cost of $2.90 per ton if three ACD's, two skidders, and the crane had been used.

Cranes were selected as the fuel-loading equipment because of their multifunctional capability. They handled the ACD and auxiliary equipment as well as placing the slash material into the burning pits. The logs were relatively easy to handle with the cranes' clamshells or grapple tongs. Logs were placed into the pits with precision, with minimum encounters with the pit walls or the ACD nozzle. The cranes were also used to clean sluffed dirt out of the pit bottoms.

Root wads historically have presented a disposal problem. They now can be economically burned in an air curtain burner. Handling and loading such material into the air curtain destructor can be done by the Pemco Cable Cruncher, already described, or a similar device.

Geometry of the burning pits is critical for emission control, especially during start-up and on windy days. The 8-ft width is the most critical dimension. If the pit becomes too wide, air curtain efficiency is affected, and air blows across and out instead of down into the pit. When this happens, ash and sparks are carried out of the pit, and the "destructor" effect of high temperatures, excess oxygen, and long-particle-suspension time is lost.

Figure 54. DriAll Air Curtain Destructor.

Figure 55. Air Curtain Destructor consuming cull logs.

Figure 54 shows the crane loading stumps and cull logs into the DriAll ACD pit on the Mt. Hood. Fire is burning at 2,000° F with no smoke. Material being burned is Douglas-fir with a moisture content of 55 percent. Figure 55 shows a virtually smokeless 2,300° F fire consuming cull logs, also on the Mt. Hood.

During all tests we loaded the pit and ran the ACD blower for 8 hours, keeping the pit fully loaded, and then ran the blower 2 additional hours after the crane and skidder quit loading. We felt this was the minimum number of hours per day that the burning operation should be conducted. Ideally, the operation should run continuously to maintain high pit temperatures and combustion rates. Nevertheless, when the minimum-hour operation was used, the fire did not extinguish overnight, and in the morning only a few logs remained unconsumed among the coals in the pit. A new fire was easily started by adding more wood.

Tests showed that a fire with peak temperatures of 1,600° F can be reached within 1 hour after ignition with relatively dry wood, i.e., less than 30 percent moisture. However, 2 to 4 hours may be required to reach the same temperature when the fuel moisture content exceeds 50 percent.

Visual smoking readings (21) showed the emission density to be less than 1/2 Ringelmann (10 percent opacity) over 95 percent of the time. Typically, the smoke was invisible. Visitors arriving at the test site were usually unaware of any fire until they got close enough to the pit to feel the heat. The only periods of higher smoke reading were during the first 15 to 20 minutes of start-up, when the smoke was closer to No. 2 Ringelmann (40 percent opacity), and occasionally a brief column of smoke and fly ash would escape the pit if the air curtain were interrupted by the crane bucket attempting to carefully place a huge log into position on the fire. This latter phenomenon was not noticed, however, after high pit temperatures were reached. Ringelmanns of 3 to 4 were sometimes observed for 2 to 3 minutes when large quantities of diesel fuel were used for initial ignition without extra oxygen.

Each morning a thin layer of ash would be left on the pit floor. Among this ash were usually from two to six scattered, large cull logs that did not burn because they were isolated from sizable coals. However, these logs and the ash were always consumed with the next day's fire, and there was never a noticeable buildup of ash on succeeding days. Overall, the unburned residue was much less than 1 percent.

An occasional spot fire was ignited by flying cinders from the ACD, especially on days when the wind gusted lengthwise along the pit. Gusty winds greater than 15 mph disrupted the air curtain when blowing 90° to it. Practically all spot fires were kindled downwind from the pit within 40 yd, and all were easily extinguished with a shovel or a man's boot heel. Since there is little chance of an escaped, uncontrolled fire, provided pit sites are well chosen, we feel burning with the ACD is much safer than traditional broadcast or pile burning.

The DriAll ACD adequately demonstrated its ability to burn, without significant air pollution, a variety of logging slash and root wads. The per ton costs are comparable to broadcast and pile burning; the per acre costs are on the order of four times as great. Despite this, the ACD should receive wide use as a logging slash disposal tool, especially at YUM sites to burn material that cannot be utilized.

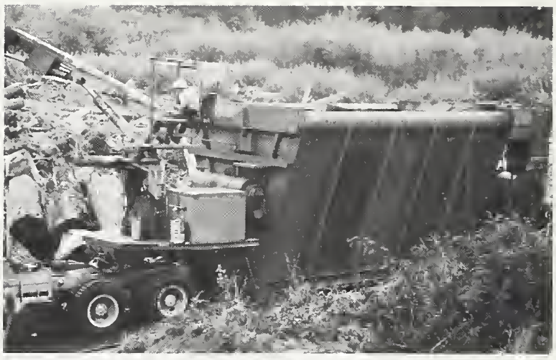


Figure 56. Camran Air Curtain Combustion Unit.

Thermal Airblast Incinerator

A device similar in design and operation to the ACD is the Thermal Airblast Incinerator. We have no direct experience with this equipment. The specifications for the two models offered are:

	Model 24	Model 36
Length (ft)	24	36
Blower output (cfm)	23,000	35,000
Diesel engine (hp)	80	120
Capacity (tons/hr)	5-15	8-25

Visually, the biggest difference in Thermal's design compared to DriAll's is the series of extended tabular nozzles mounted on the discharge manifold. These deliver the air for the curtain. Thus, the Airblast Incinerator is essentially a combustion air blower connected by a flexible duct to the 24- or 36-ft heavy-gauge steel manifold assembly. Cantilevered from a 18-ft long x 7-ft wide sled base, the manifold is easily adjustable for best angle and height to assure maximum burning rate and efficiency. The screw-in nozzles are relatively inexpensive and quickly replaceable should they become distorted after prolonged exposure to the heat. As with ACD's, a pit must be excavated in stable ground and the manifold positioned along the pit's edge. Recommended pit dimensions are 24- or 36-ft length, 10- to 12-ft width, and 12- to 15-ft depth.

Camran Air Curtain Combustion Unit

The Air Curtain Combustion Unit (ACCU) is a mobile burning enclosure that uses air curtain principles (fig. 56)

The unit consists of a trailer-mounted, hopper-shaped combustion unit with 6-in-thick precast refractory wall panels. These panels have longitudinal forced-air ducts to cool the steel at the panels' outer surface. Air travels down the paneled sides to pass through the grates, cooling them and creating underfire combustion air. The main flow of forced air is driven by a 125-hp diesel engine via plenums over the burner to form the 20,000 cfm at 7,000 fpm air curtain. Continuous ash removal from the unit is possible through the grates at the bottom. To minimize smoke at startup, the unit comes with a propane gas light-off system. Loading can be done with a crane, a high-lift front-end loader, or with a custom-designed continuous feeder.

A medium-size 10- to 15-tons-per-hour unit measures 14-ft high x 14-ft wide x 20-ft long, has a 1-ft underbody clearance, and weighs about 45,000 lb. The units cost about $25,000. Also available is a skid-mounted "Portapit" unit that is 10 x 8 x 20 ft.

We observed the ACCU equipment in a demonstration at the Foster Reservoir, near Sweethome, Oreg., late in 1972. The combustion unit consumed old logs, 5- to 10-ft in length and 2- to 4-ft in diameter, that had been submerged in the reservoir. The integrally mounted grapple loaded the logs into the unit. The Camran ACCU emitted no smoke, ashes, or cinders and appeared to be pollution-free. The residue was much less than that left by broadcast or pile burning. The unit cost about $65 per burning hour to operate.

In early 1973, a second ACCU was seen on another reservoir slash cleanup project— this time at the Bullard's Bar Reservoir in Northern California. The ACCU was on a 40 x 100-ft barge along with a 65-ton crane that had a 96-ft boom. About 20 tons per hour of slash flotsam was burned without creating visible emissions.

Thus, the Camran burner could be used as an air curtain burner in areas where not enough material exists to dig a pit, or it can obviously be used to clean up reservoirs. If, however, enough material is present on the forest floor to allow a week or more of operation, the pit burners would probably be more economical. If a shorter run is required or the soil is not suitable for a pit, the ACCU should probably be used.

OTHER SLASH TREATMENTS

In addition to mechanical and burning equipment for the treatment of slash, other approaches have been investigated. These are briefly discussed in the paragraphs that follow.

Exportation

Loading slash onto logging trucks or similar vehicles and hauling it away from the forest is known as exportation. At present, exportation is generally not a good approach to the slash problem because of the high cost of handling, loading, and transporting. Large costs are incurred because it is difficult to get a truck into the vicinity of logging or TSI slash. Loading the slash onto a truck has to be done manually or, at best, by small, low-capacity machines. However, as the economic value of slash increases (as is currently happening since more and more chips are needed for paper making and structural particle board) exportation becomes more attractive.

Another factor that is tending to increase the appeal of exportation is the accelerating acceptance of Yarding Unmerchantable Material (YUM) and Piling Unmerchantable Material (PUM) clauses in Forest Service timber sale contracts. If a timber sale contract contains YUM or PUM provisions, the contractor must either yard to the landing, or pile, all slash over a certain size—usually 5-in to 8-in in diameter. Since YUM and PUM requirements result in gathering slash from the logged area, exportation is greatly facilitated. Until slash can be sold at a profit, exportation is presently senseless because there is the problem of disposal once slash has been hauled from the forest.

There are also biological considerations. Some scientists voice concern that if all wood fiber were removed from timber sites, site quality would suffer over the long term. In general, at this time exportation does not seem to be a useful treatment technique for any type of slash. However, as more complete utilization of the total tree becomes profitable in coming years, more and more slash will be hauled to barking-chipping plants.

Burying

On the Deschutes National Forest, Oreg., a project was observed in which cells for burying logging

slash were prepared with a D8 tractor. Slash piled the previous year was pushed into the cells and was then covered with at least a foot of dirt. This approach to slash treatment at first appeared attractive, especially aesthetically, but several drawbacks soon appeared. It is not as economical as it may first seem. Costs of about 5 percent over those normally experienced in pile burning were incurred. Settling of the surface at the burial site occurred.

A large ultimate concern was that buried slash decomposes very slowly and the burying site was in essence an area taken out of timber production. Other disadvantages of slash burying are that slash cannot be buried in rocky or steep grounds, and that large cull logs and snags are difficult to bury.

A unique method for the disposal of clearing slash on road construction by burying has been proposed by the Northern Region's Division of Engineering (15). Rather than merely pushing slash into a pit, it is suggested that slash be arranged carefully in the toe of a fill, such that it will contribute to the stability of a roadbed.

All-in-all, burying of logging or road construction slash might have limited use as an acceptable alternative to broadcast or pile burning. Burying of TSI slash is not seen as a reasonable approach because the slash material is very loose. This low-density material presents a large volume of slash to be dealt with at each thinned site.

Explosives

The use of explosives in slash disposal is an expensive and difficult proposition. For instance, explosives have been used by the Forest Service for clearing fire lines (4); however, their use is restricted to those having a blaster's permit. Explosives have also been used effectively to break root wads. But they are not useful in reducing other forms of slash, according to work performed at the Missoula Equipment Development Center. Our investigations of explosives lead us to believe that explosives do not have a place in slash disposal.

Biological Control

Although the notion persists that some biological control method could be applied to hasten slash decomposition, this concept of introducing bacteria has, to date, proven fruitless.

CONCLUSIONS AND RECOMMENDATIONS

Equipment designed and built specifically for treating forest residues, tested under a range of forest conditions, is needed. Unfortunately, most of the equipment that has been used or tested for slash treatment was designed without consideration of the engineering problems of slash treatment. And equipment modified or built specifically to treat slash has suffered from design and engineering problems. Also chipping devices for the utilization of logging slash incur high manpower costs. Since there is a large volume of logging, road construction, and TSI slash on the ground (with more being created every day), for the short-term, better equipment needs to be designed, manufactured, and made available to reduce slash or chip it into an acceptable residue. Also it appears that the best treatment for the unusable portion of heavy slash is air curtain burning.

Thus work is continuing at the SDEDC slash treatment facility to complete gathering basic information on the shapes, speeds, and general configurations of cutting heads suitable for slash reduction. This controlled engineering experimentation, it now appears, is by far the best approach to developing and optimizing slash treatment and utilization equipment. We are monitoring new developments offered on the market, but at this time have no plans to test each new available piece of equipment.

For the long term, new approaches to logging must be developed that consider the slash disposal problem as part of the total harvesting effort. The entire tree growing activity, from seedling to lumber, should consider utilization of the "whole tree." This nation needs all of the tree—both the quality lumber and the remainder of the tree. The latter not only to make pulp for cardboard and paper production but also for forming, with the aid of resins, panels for wall modules, floors, etc. Thus, in the long run the slash problem should resolve itself, as every part of the tree gains economic value, and the right equipment becomes available to process and transport all portions of a tree in a cost-effective manner.

Specifically, for the near term, we must develop methods for utilizing heavy logging and road construction slash and for treating the lighter residue. Our need is a slash recovery system having well-engineered equipment, coordinated with cost-

effective operations to remove, preprocess in the field, and then transport culls and other slash material to utilization mills.

We must determine the best on-site barking and cleaning methods, the best size for on-site preprocessed wood, the necessary transportation and handling equipment, and, most important, the end use of the processed material. Since all of these parameters are interdependent and inseparably related to the commercial market for the end product, and since the market is dependent on development of an economical slash recovery system and general public acceptance of new forms of wood products such as structural particle board, any new equipment developed through this effort will have to be based on exhaustive engineering and marketing studies and careful cost comparisons.

Utilization schemes should profitably include all material over 6-in in diameter. A cost-effective method for in-place treatment of smaller slash is required. In treating the smaller material, all aerial fuel must be broken or crushed and all pieces, including stems, must be reduced in size so that they will not interfere with fireline construction or forest management objectives.

As to TSI slash, we wish to shortly begin field testing prototype equipment that will simultaneously thin and treat slash to an acceptable degree. This equipment must incorporate the latest technology now being developed in the Forest Service slash cutting test facility and meet the following minimum criteria:

1. *Cost.* The cost should be comparable to, or less than, presently used methods for the same level of treatment.

2. *Terrain Ability.* The immediate goal is to treat slopes up to 20 percent and, through technological improvements, advance to steep slopes.

3. *Residue.* Aerial fuels should be cut or broken into pieces that are then randomly scattered on the site. Piece size must be small enough not to interfere with firefighting or management activities at the site.

4. *Vehicle.* If possible, the cutting or treatment equipment should be mounted on a proven, commercially available vehicle.

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APPENDIX

Criteria for Treatment and Utilization Approach Acceptability

The "point-of-view acceptability" columns in tables 1, 2, and 3 that rate treatment equipment and methods for the three types of slash (logging, road construction, and TSI) that are created in the field represent the quality of treatment based on the various Forest Service management considerations listed (i.e., aesthetics, watershed, etc.). The ratings are based upon the total slash treatment—both the considered equipment or method, as well as the listed support equipment. A detailed explanation of the meaning of the rating numbers (a possible 1 through 5 in each case) follows.

Aesthetics

1. A superior job of cleanup. Residue is either invisible or pleasingly arranged; most observers (both professionals and the general public) would feel that the aesthetic aspects of the forest have not been disturbed or have even been enhanced. No smoke. No appearance of logs left on site or of wasted resources.

2. Generally acceptable aesthetic treatment. Some evidence of disturbance—such as small concentrations of chips, etc. Only a small amount of smoke. Little indication of logs left on site or of wasted resources.

3. We might expect some complaints from the more purist observers. Aesthetics here would be only marginally acceptable alongside heavily traveled roads, and certainly would not be acceptable alongside forest highways or any areas of exceptional scenic beauty. Significant smoke. Significant amount of cull logs and appearance of wasted resources.

4. A poor job of aesthetic treatment conditionally acceptable only to knowledgeable forest officers who realize that the time factor will ameliorate the condition. Large number of logs left with appearance of much wasted resources.

5. Completely unacceptable. Would commonly be described as a "mess". Comparable to many clearcut areas in old-growth Douglas-fir. Usually produces smoke which is visible for many miles, and produces irritation among most people. No attempt made to clean-up heavy material. Leaves ugly impression of extensive waste of resources.

Watershed

1. Superior. No disturbance of, or even enhancement of, the before-treatment watershed condition.

2. Only slight temporary disturbance of the original watershed. In a year or so, natural growth will return the watershed to its original condition.

3. Moderate ground disturbance and disruption of the watershed condition. Several years will be required to return it to its original condition. Some surface erosion and increase in downstream turbidity might be expected for a period of up to 3 years.

4. Considerable ground watershed disruption. Some areas may require supplemental treatment to return site to its original condition.

5. Unacceptable watershed disruption. A marked increase in surface erosion and stream turbidity would be expected; natural forces would probably not heal the watershed.

Fire Management

1. A considerable reduction in rate of spread and resistance to control has been effected. No risk of accidental spotting or fire escape.

2. Some reduction of rate of spread and/or resistance to control has been effected. Slight risk of escape.

3. Fire control considerations have not been changed over the pretreatment situation. Moderate risk of escape.

4. A slight increase in resistance of control and/or rate of spread has been experienced, no more than one degree on the R-6 rating scale; i.e., from MM to HM or from LL to LM. Considerable risk of escape.

5. A severe increase in resistance to control and rate of spread, as MM to HE, comparable to the increase effected in one year after ponderosa pine is hand thinned and left untreated. Extreme risk of escape.

Timber Management

1. Seedbed harvesting conditions are improved markedly by the slash treatment; there is no impairment of growth potential. (Note: this does not include the improvement expected due to thinning, but the improvement effected by the slash treatment only.)

2. Slight improvement in site quality due to slash treatment.

3. No change in the timber management aspects of the site due to slash treatment.

4. Moderate degradation of timber management objectives caused by slash treatment only. Subsequent management operations hindered.

5. Severe impairment of timber management objectives, marked reduction in site quality. Subsequent management operations difficult or impossible.

Engineering

1. The equipment is expected to be largely trouble-free in operation and will present no problems to the forest engineers and fleet managers. It does not affect roadbeds.

2. The equipment is expected to cause some problems for forest and fleet managers, but can be repaired and kept in operating condition at a local level. No degradation of roadbeds.

3. The equipment might be difficult to maintain and would require occasional forest or regional support to keep operating properly, or it might disturb roadbeds to the point where minor maintenance is necessary.

4. The equipment would require regular forest or regional attention and considerable support from fleet management. Moderate roadbed disturbance.

5. The equipment, in its present configuration, would present an unacceptably high maintenance burden upon fleet management personnel, or would disturb the roadbed upon which it is used or transported to a point where major road maintenance would be necessary.